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Founded 1876

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Founded 1876.—Incorporated 1888

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[*Excerpt from Examination Pamphlet.*]

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EXAMINATIONS IN PRACTICAL SANITARY SCIENCE, AND FOR INSPECTORS OF NUISANCES

COLONIAL CENTRES:—Canada, New South Wales, Queensland, Western Australia, British South Africa and Hongkong

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Offices: Sanitary Board Offices, Hongkong.

The great and increasing importance of the duties devolving upon local surveyors and inspectors of nuisances, in connection with the various Acts relating to public health, drainage and water supply, the sale of food and drugs, etc., led the Sanitary Institute of Great Britain in 1877 to establish voluntary examinations, to appoint a Board of Examiners, and to grant certificates of competency in sanitary knowledge.

The Sanitary Institute, in which the older body was incorporated in 1888, are continuing this important work.

The examinations were established in 1877, and the following figures show the total number of examinations held, and the number of candidates to the end of December, 1902:—

	Examinations.	Candidates Entered.	Candidates Certificated
Local Surveyors	35	291	142
Practical Sanitary Science	65	401	188
Inspectors of Nuisances	157	7,545	4,186
Inspectors of Meat, &c.	13	152	95
Practical Hygiene of School Teachers.	4	34	25
	274	8,423	4,636

In order further to promote the advancement of sanitary science the Council of the Institute are extending their examinations to the colonies, and Boards of Examiners have been appointed in the Commonwealth of Australia, the Dominion of Canada, British South Africa, and Hongkong.

The examinations in the colonies are held under the same regulations and conducted in the same manner as in England, and the certificate is the same wherever the examination is held.

EXAMINATION IN PRACTICAL SANITARY SCIENCE.

Many persons who have no intention of becoming sanitary officers have expressed a desire to obtain a certificate from the Sanitary Institute indicating their knowledge of sanitary science, and the Council have arranged a syllabus, which, although not including many technical subjects that an inspector is required to know, is of a higher standard than the inspectors' examination as far as relates to practical sanitation. The examination is arranged so as to be suitable to foremen of works, builders, and those engaged in allied trades, managers of property, lecturers, and others requiring a thorough knowledge of practical sanitary science. *(The syllabus of the examination is given on pp.* 9 *and* 10*)*

EXAMINATION FOR INSPECTORS OF NUISANCES.

The examinations are intended to enable inspectors of nuisances, or persons desirous of becoming such, or of obtaining the certificate of the Institute, to prove their competency by examination. It is essential that candidates should have a practical as well as a theoretical knowledge with the subjects set out in the syllabus (*see pp.* 7 *and* 8).

Examinations are also held in Great Britain for inspectors of meat and other foods, and in practical hygiene for school teachers.

The Local Government Board, London, accept the certificate of the Sanitary Institute as evidence that the person possessing it is qualified for the office of inspector of nuisances in any Urban or Rural district outside London; it is also recognised by the Local Government Board, Edinburgh, and the Local Government Board, Dublin, and many Local Boards and Corporations require candidates, when making applications for appointments, to produce a certificate of this kind. A register of successful candidates is kept at the offices of the Institute, and a copy will be forwarded to Local Boards and Sanitary Authorities on application.

REGULATIONS FOR BOTH EXAMINATIONS.

Every candidate is required to furnish the Board of Examiners with satisfactory testimonials of recent date as to age and personal character; these should, if possible, be from a clergyman, medical man, or someone holding an official position.

(1) The candidate must be able to write legibly and spell correctly;
(2) Be able to make an outline sketch to scale;
(3) Must possess a fair knowledge of arithmetic;

so that he may be able to prepare a report on any subject connected with his duties, creditable to himself and to the authority employing him.

Candidates who present themselves for examination for inspectors of nuisances subsequent to January, 1904, will be required at the time of making their application to furnish satisfactory evidence that they have had opportunities of gaining a practical knowledge of sanitary work.

The following persons will be considered admissible:—

(*a*) A surveyor or assistant surveyor to a Local Authority, or inspector of nuisances holding or having held office for at least three months.
(*b*) An accredited member of a profession or trade having a direct connection with public health.
(*c*) A person who has obtained a certificate in a prescribed form from a medical officer of health, surveyor to a Local Authority, or an inspector of nuisances, that he had sufficient opportunities of gaining practical knowledge of the work and duties of an inspector of nuisances. The certificate to contain a statement of the time devoted to the study by the candidate.
(*d*) Such other persons whose qualification may from time to time be approved by the Council.

Application for examination must be made on the proper form, and must be sent to the local office of the Institute fourteen days before the date of the examination at which the candidate wishes to present himself.

The fee payable for either the practical sanitary science examination or the inspectors of nuisances examination is $35. It must be paid to the local secretary: $5 on making application, and the remainder at least one week before the day of examination.

The examination occupies a portion of two days. On the first day it consists of written papers only, three hours being allowed. On the second day the examination is *vivâ voce*, with one or more questions to be answered in writing if required.

A certificate of competency, bearing the seal of the Institute, is granted to each successful candidate.

A certificate is not granted to any candidate under 21 years of age.

An unsuccessful candidate is allowed to present himself a second and third time for examination within two years of his first application on payment of half fees; but in every case the candidate must make application on the prescribed form previous to presenting himself for examination.

Any person having passed the examination in practical sanitary science and received the certificate is, by virtue of having such certificate, upon proposal and election a member of the Institute, called upon to pay only the reduced subscription of £1 1s. annually.

Any person having passed the examination and received the certificate for inspector of nuisance is, by virtue of having such certificate, upon proposal and election as associate of the Institute, called upon to pay only the reduced subsciption of 10s. 6d. annually.

In order to make the examinations more accessible to candidates, the Council have arranged for them to be held in various centres during the year.

EXAMINATION FOR INSPECTORS OF NUISANCES

SYLLABUS OF SUBJECTS.

The provisions of the Acts and Model Bye-laws relating to the duties of inspector of nuisances.

Candidates locally examined will be expected to show a thorough knowledge of the laws in force in their own province and district, and a general knowledge of the provisions of the British public health statutes.

A knowledge of what constitutes a nuisance.

Methods of inspection of dwellings, common and other lodging houses, cellar dwellings, dairies, milk-shops, markets, shaughter-houses, cow-sheds, and nuisances especially connected with trades and manufactories.

The physical characteristics of good drinking water; the various ways in which it may be polluted during collection, storage, or distribution, by damage to supply works or in houses, and the means of preventing such pollution; methods of water supply.

The pollution of rivers, lakes, and ponds.

The characteristics of good and bed food (such as meat, fish, milk, milk products, vegetables, and fruit).

The regulations affecting persons suffering or recovering from infectious diseases, and some knowledge of such diseases; the principles of ventilation, and simple methods of ventilating rooms; the principles of calculating areas, cubic space; interpretation and drawing of plans and sections to scale.

Disinfectants and methods of disinfection.

A knowledge of the general duties of the office, and methods of keeping the necessary books and records; writing and spelling.

The proper conditions of good drainage; a knowledge of various systems of drainage and their adaptability to particular conditions; the advantages and disadvantages of various sanitary appliances for houses; the inspection and management of the sanitation of native and other locations, with the legislation dealing therewith; scavenging and the disposal of refuse.

For the convenience of candidates, a *pamphlet is published containing particulars relating to the several examinations, copies of the examination papers set at previous examinations, and other information useful to students.

Questions set at examinations beyond those in this pamphlet are published in the supplement to the "Journal" of the Institute, price 4s. 6d. per annum, or 1s. 2d. each quarter, post free.

NOTES FOR STUDENTS AND CANDIDATES FOR THE EXAMINATION.

In preparing for the duties of a sanitary inspector a large amount of knowledge can be advantageously obtained in class lectures and demonstrations; but part of the work of preparation must necessarily depend upon individual study and observation on the part of the candidate, and they are recommended to pay careful attention to the following points:—

By observation and enquiry to obtain a practical familiarity with sanitary work, the procedure and duties of a sanitary inspector, a knowledge of building materials and appliances, and the enquiries to be made in the case of infections diseases and reported nuisances, to see an underground dwelling or bakehouse, to ascertain the routine of the work and the books used in a Public Health Office, and to attend a case in court.

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* *This Pamphlet can be obtained from the Local Secretary,* Dr. B. Barnett, *Sanitary Board Offices, Hongkong. Price Sixpence* (30 *cents*).

A knowledge of building materials must be obtained by actually handling and examining the materials themselves. This can be done at building works in progress in addition to examining the specimens in the Parkes Museum. Students should make an individual visit to any ordinary bakehouse, slaughter-house, and police-court, etc., and make opportunities of seeing practical sanitary work in the district in which they live.

The writing of a clear, accurate report on sanitary matters is also an important part of an inspector's duty, and spelling and composition should be carefully attended to in the answers to examination questions, and should be practised by the candidates. Elaborate drawings are not required by the examiners, but all candidates should be able to make a sketch sufficiently good to indicate the general arrangement or placing of sanitary apparatus. They should learn to understand plans and sections drawn in the ordinary way.

In mensuration and calculation candidates should set out clearly at the beginning of their answer the process or formula by which they are working the calculation; and in many cases a good diagram would add to the value of the answer. The calculations made by the candidates should be shown in full.

In order to assist those candidates who propose to prepare themselves for the duties of a sanitary inspector, the Council of the Sanitary Institute have addressed a letter to the sanitary authorities in England, asking if they would grant facilities to suitable candidates for going round with the acting inspector on some of his visits at certain convenient times, in order to gain a practical insight into the duties of a sanitary inspector.

It was thought that some arrangement of this kind would be advantageous to the public health service as well as to the candidates themselves, because it would enable sanitary authorities, in making appointments, to select men who had already received some practical training before taking up their duties.

In response to this circular letter, the authorities in many districts have already replied that they are willing to grant the facilities under certain conditions.

The conditions embody the following points, but vary in different towns:—

(1) Each person desiring to avail himself of the facilities for study afforded by the department (with the view of qualifying for an inspectorship) must satisfy the M.O.H. that he is a suitable candidate to enter for the examination, with a fair prospect of success when examined, and that he is a fit and proper person to act as a sanitary inspector when sufficiently instructed.

(2) He must state at the outset the period during which he desires to study the work of an inspector.

(3) During the period of study he must place himelf for not less than six hours weekly under the direction of the M.O.H. and the inspector or inspectors

of the district in which he is to work, and these officers will arrange for his employment as far as possible in the capacity of a temporary assistant to the inspector in the various duties the latter is called upon to perform.

(4) At the end of his period of study he shall receive a letter stating the length of time he has devoted to the acquistion of practical knowledge of an inspector's duties, and as far as possible the actul work at which he has assisted, or which has come under his observation.

Candidates are advised to avail themselves of these opportunities, as practical knowledge is essential in order to pass the examinations, and those candidates who present themselves for examination subsequent to January, 1904, will be required at the time of making their application to furnish satisfactory evidence that they have had opportunities of gaining a practical knowledge of sanitary work.

It is suggested that before taking up any course of prepartion, students should make enquiries of the Institute or at the local office as to the nature of the training that should be obtained.

Further information with respect to the arrangements will be published in the "Journal," or can be obtained from the office of the Institute.

A course of lectures and demonstrations is arranged by the Institute for the students for this examination.

A list of publications for the use of students is given on page 11.

QUESTIONS SET AT PREVIOUS EXAMINATIONS HELD BY THE INSTITUTE.

Inspectors of Nuisances.

1. Where bye-laws are in force respecting houses let in logdgings, mention some of the special sanitary regulations affecting such houses (as set out in the Public Health Act, 1875) which would come within the inspector's cognizance.

2. How would you disinfect (*a*) bedding, (*b*) books, and (*c*) harness, saddery, etc., after small-pox?

3. Under what conditions would you condemn a carcase showing signs of tubercle in the case of (*a*) a cow, (*b*) a pig?

4. Describe fully the process of laying on water from the main in the street to the sink, bath, and w.c., of a 12-roomed house. State diameter of the pipes to be used, and depth below the ground at which they should laid, the positions of the stop-cocks, the kind of taps, and the precautions necessary to prevent waste.

5. In the Model By-Laws issued by the Local Government Board (England), what provision is made for open space at the rear of a dwelling, and how it is to be measured?

6. Give the cubic contents of an attic room, the floor area of which is 13 ft. 6 in. × 18 ft. The room has a flat ceiling 9 ft. from the floor, but the roof slopes on all sides with a pitch of 45° to meet the walls at a height of 6 feet from the floor.

7. Make sketches explanatory of the following:—
    (1) Connection between soil pipe and house drain.
    (2) Inspection-chamber.
    (3) Fresh air inlet.
    (4) Anti-syphonage pipe.

8. What forms and books would you use in connection with the removal of patients to hospital, the disinfection of houses, and the exclusion of school-children from infected houses?

Inspectors of Nuisances.

1. State all the points to which you would direct your attention in the inspection of a bakehouse.

2. Explain in what way any of the points noted in question No. 1 may affect either (1) the flour, or (2) the bread.

3. Calculate the cubic capacity of a room 25 ft. × 16 ft., walls 10 feet high, having a gable roof, the top of which is eighteen feet from floor. How many work-people will this accommodate?—
    (1) In your opinion;
    (2) According to by-laws of industrial establishments.

4. What immediate surrounding circumstances would you consider detrimental to the establishment of a bakehouse?

5. Discuss the principles of natural and artificial ventilation.

6. Describe the essentials of a good trap. Draw rough sketches of any with which you are acquainted.

7. Enumerate the various things which constitute a nuisance under the Quebec Public Health Act.

8. Describe precisely the procedure to be followed in taking a sample of food for analysis. Under what Act or By-laws do you get authority?

LECTURES TO SANITARY OFFICERS.

The following lectures, which form part of the complete course of lectures and demonstrations given in the spring and autumn by the Institute each year, are published in the "Journal" of the Institute, and can be obtained at the offices, 72, Margaret Street, London, W.

Signs of Health and Disease in Animals destined for Food, when Alive or after Slaughter; Tuberculin and other Tests - - - - } Price 2/9, post free.

The Names and Situations of the Organs of the Body in Animals - - - - - Practical Methods of Stalling and Slaughtering Animals. By W. HUNTING, F.R.C.V.S. -	Price 2/9, post free.
House Drainage and Sanitary Appliances (Illustrated). Two Lectures by W. C. TYNDALE, M.Inst.C.E. - - - - - -	do.
Calculations, Cubic Measurements, Ventilation, Warming, and Lighting (Illustrated). Two Lectures by W. C. TYNDALE, M. Inst. C.E. -	do.
A series of headings for the various Books, Forms, and Registers in ordinary use in the office of a Sanitary Department - - - - -	Price 1/-; to Students 6d.
Particulars of Sanitary Works and Undertakings Demonstrated to the Students during the Course of Lectures - - - - -	do.

OBJECTS OF THE INSTITUTE. RULES FOR THE ADMISSION OF MEMBERS, &C.

THE OBJECTS OF THE INSTITUTE ARE—to promote the advancement of sanitary science in all or any of its branches, and to diffuse knowledge relating thereto.

SESSIONAL MEETINGS—of the Institute are held in London from time to time, for the reading of papers and for discussions upon subjects connected with sanitary science.

JOURNAL.—The "Journal" of the Institute is published quarterly, each part containing about 140 super royal 8vo pages, and a supplement of 40 pages. It includes, besides the papers and discussions at the meetings of the Institute, a number of other items of interest to those working in public health, a descriptive epitome of the titles of all articles appearing in the various British and Foreign journals, reviews of sanitary publications, notes on law cases and legal decisions relating to public health matters, and general notes. The "Journal" is supplied free of charge to members and associates of the Institute.

COURSES OF LECTURES—and demonstrations for sanitary officers, specially adapted for candidates preparing for the examinations of the Institute, are held twice a year in London, and at intervals in the provinces, preceding the examinations; a nominal admission fee is charged for each course.

EXAMINATIONS—are held, and certificates of competency in sanitary knowledge are granted. The examinations at present arranged are in Practical Sanitary Science; Inspectors of Nuisances under the Public Health Act, 1875;

Inspectors of Meat and other Foods; Practical Hygiene for School Teachers. The examinations are held in London and also in provincial and colonial centres.

A CONGRESS—for the consideration of subjects relating to hygiene, and an exhibition of sanitary apparatus and appliances, are held by the Institute.

THE PARKES MUSEUM—which is maintained by the Institute, contains a great variety of the most approved forms of apparatus and appliances relating to health and domestic comfort.

THERE IS A LARGE LIBRARY—of sanitary literature, which contains, in addition to standard works on sanitary science, a collection of reports of medical officers of health over the whole country; and a reading room supplied with the principal sanitary periodicals, both home and foreign.

MEMBERSHIP.—Annual subscription for those residing abroad, £1 1s.; life composition, £21. Associateship, £1 1s.; life composition, £10 10s. Associates who have passed the inspectors' examination, 10s. 6d.

FORMS OF APPLICATION—for admission to the Institute, and the examinations, and all further information, can be obtained from the secretary.

FORMATION OF THE HONGKONG BRANCH

In the City Hall, Hongkong, on October 6th, 1903, a large number of the members of the Sanitary Department, local architects, and persons interested in sanitary matters assembled, the occasion being the formation in Hongkong of a branch of the Sanitary Institute. Amongst those present were H. E. Sir Henry A. Blake, G.C.M..G, Sir John Keane, Hon. H. E. Pollock, K.C., Hon. Gershom Stewart, Colonel Webb, R.A.M.C., Drs. Drew, R.N., Atkinson, Pearse, Barnett, Macfarlane, and Keyt; Messrs. Hewett, Ough, A. G. Wood, and G. A. Woodcock.

H. E. the GOVERNOR, in his introductory remarks, said that every gentleman in the room would understand how important was the series of lectures to be delivered, between now and the 16th February, to all those in Hongkong who took an interest in the sanitary condition of this great city; but as he did not wish to anticipate anything the lecturer might say he would ask Dr. Atkinson to deliver his lecture.

The Hon. Dr. ATKINSON said: Your Excellency, and Gentlemen,—I am sure I am voicing the opinions of all present when I say how much we appreciate your kindness in coming to-night, sir, to open this the first session of the Hongkong Branch of the Sanitary Institute. The Sanitary Institute of Great Britain has been established since 1876. Its objects are to promote the advancement of sanitary science in all or any of its branches, and the diffusion of knowledge relating thereto. The Council is composed not only of medical officers of health and physicians, but also of eminent architects and engineers. The work of the Institute began with the examination of sanitary inspectors, but it is now something more than that: there is a permanent museum, the Parkes Museum in Margaret Street, London, which contains a great variety of appliances and apparatus of the most approved forms, relating to health and domestic comfort; there is a large library of sanitary literature, which contains, in addition to standard works on sanitary science, a collection of reports of medical officers of health over the whole country, and a reading room supplied with the principal sanitary periodicals both home and foreign; it holds congresses and conferences by means of which many important practical conclusions have been arrived at. This society, although founded in London, is not only English, or British, but claims to be Imperial in the true sense of the word. Branches have already been formed in Australia, South Africa, and Canada, and I believe one has been, or is shortly to be, established in India. I mention this to show that the ambition of the society was not confined in its scope.

Hygiene is of world-wide importance, and situated as we are on the borders of one of the most ancient civilisations of the world, how great are our opportunities and responsibilities in this respect! It is only within the life time of this colony that sanitary science has made for itself a name even in England—amongst its pioneers I would mention Farr, Simon, Parkes, and the elder Chadwick. To the Chinese sanitation is an unknown name; and who knows what a leavening influence this small society may ultimately effect on that empire. This local branch owes its inception to one of the senior sanitary inspectors who were obtained from England in 1902. I refer to Mr. Carter, who is, I understand, the only member of the Institute east of Suez, and I regret to say he is unable to be here to-night owing to an attack of dengue. He it was who first suggested the idea of the establishment of a branch of the Institute in Hongkong, and last winter lectures were delivered by Drs. Clark, Pearse and Hunter, and Messrs. Gibson and Browne in order to see whether there was any demand for such a course. The attendance at these lectures was very encouraging, and before Dr. Clark left for home on leave, he addressed the home Institute in order to ascertain whether they were willing to establish a branch here. A favourable reply was received, and then the subject was broached by Dr. Pearse and myself to the Sanitary Board. The members heartily approved of it, and with the consent of the Government, a semi-public meeting of those interested was held at the Sanitary Board offices, and offers of support were received, not only from several of the local architects and engineers, but also from some of the military officers. It was at that meeting decided to establish a local branch in Hongkong, and a small committee was appointed to make the necessary arrangements for a course of lectures in the coming winter. We were fortunate in obtaining the services of Dr. Barnett, one of the assistant Medical Officers of Health, as secretary. The use of a suitable lecture-room has been obtained at Queen's College, and lectures are to be given twice a week on Tuesday and Friday evenings, at nine o'clock. At the end of the session two examinations will be held, one in practical sanitary science and the other for inspectors of nuisances. The former is for persons who have no intention of becoming sanitary officers, but who desire to obtain a certificate from the Institute indicating their knowledge of sanitary science. This, although not including many technical subjects which an inspector is required to know, goes beyond the scope of the inspectors' examination, as far as relates to practical sanitation. The examination is arranged so as to be suitable to foremen of works, builders, and those engaged in allied trades, and others requiring a thorough knowledge of practical sanitary science. Every candidate is required to furnish the Board of Examiners with satisfactory testimonials of recent date as to age and personal character. Applications for examination must be made in a proper form, and must be sent to the office of the Institute fourteen days before the date of the examination at which the candidate wishes to present himself. The fee payable for the examination is $35, which must be paid to the secretary. The examination in practical sanitary science occupies two days; on the first day it consists of written papers only. There are two papers, two hours being allowed for each, and on the second day the examination is *viva voce*. A certificate will be granted to each successful candidate. A certificate is not granted to any candidate under 21 years of age. The syllabus for subjects includes :—Elementary physics and chemistry in so far as they apply to sanitary science. The principles of hydraulics and hydrostatics, pneumatics and heat, and the composition and properties of air and water, etc., including the principles involved in the various methods of treating sewage. Local Conditions :—metereology; soil and subsoil and its drainage; sanitary precautions as to healthiness of site, &c. Water :—sources of supply: mains, pipes, fittings and storage; sources of contamination and protective precautions; filtration: materials and construction general description of materials used in construction, *viz*, timber, metals, concrete, stones, bricks, and tiles, cement, mortars, materials for covering roofs, coverings for same, gutters, &c., fire-proof construction. Air, lighting and warming :—principles of ventilation. air-space and quantity required; overcrowding surface and in buildings, size of windows, ventilation of public buildings, hospitals, schools, dwellings and houses. Drainage. Sewage and sanitary appliances :—the planning and construction of drains and sewers, advantages and disadvantages of various sanitary appliances, drain-testing and inspection of drainage-work, the various methods of dealing with house-sewage and house-refuse, disposal of sewage and refuse. A more detailed list will be found in the printed syllabus. It is essential that candidates should possess a practical as well as a theoretical acquaintance with the subject. With regard to the examination for sanitary inspectors the same conditions are to be complied with as in the former examination. The subjects for examination are :—elementary physics and chemistry in relation to water, soil, air and ventilation; elementary statistical methods—hygiene of communities including prevention and abatement of nuisances, sanitary defects in and about buildings and their remedies; water supplies—drainage; refuse-removal and disposal, offensive trades, disinfection; food-inspection, the characters of good and bad food; The regulations affecting persons suffering, or recovering from infections diseases and some knowledge of such diseases. Principles of ventilation, measurement of cubic space, &c. A knowledge of the general duties of the office, and methods of keeping the necessary books, writing, and spelling. The provisions of the Public Health Ordinance and the by-laws made thereunder, a knowledge of the Sale of Food and Drugs Ordinances. Every candidate who passes the examination will receive a certificate to that effect qualifying him for appointment as sanitary inspector. The examinations are intended to make inspectors of nuisances, or those desirous of becoming such, or of obtaining the certificate of the Institution, to prove their competence by examination. Many local boards and corporations require candidates, when making application for appointments, to produce a certificate of this kind, and I am sure that the possession of such a certificate would considerably influence the Sanitary Board in its recommendation for the promotion of inspectors from one class to another. I may mention that we have started the nucleus of a library and a reading-room at the district offices in the Central District, 56, Hollywood Road. We hope in time to have a good reference library there. The first lecture will be delivered by Mr. Browne on Friday evening next, in No. XI room, Queen's College, to commence at 9 p.m., the subject being Mechanical Physics.

LECTURES.

From October 9th, 1903 to February 26th, 1904, 35 lectures and 2 demonstrations were given by the following gentlemen:—

Dr. W. W. PEARSE	10	Lectures
Mr. A. H. OUGH	5	,,
,, J. J. BRYAN	4	,,
Dr. W. HUNTER	3	,,
,, A. GIBSON	3	,,
,, ,,	2	Demonstrations
Capt. FITZWILLIAMS	2	Lectures
Mr. F. BROWNE	2	,,
,, L. GIBBS	2	,,
,, J. LEMM	2	,,
,, BROTHERTON HARKER	1	,,
,, D. JAFFE	1	,,

The number of students attending averaged per lecture—

Government Servants	12.00
Other Candidates	10.43
General average	22.43

Examinations were held on March 29th and 31st, 1904, in practical sanitary science and for sanitary inspectors.

Seven candidates presented themselves for the first, of whom four were recommended for Pass; eleven candidates for the second of whom eight were recommended for Pass.

A prize of $50 worth of books presented by Mr. Fung Wa Chun was awarded to H. J. W. Gidley for good results in the sanitary inspectors' examination, and a prize of $25 worth of books presented by Dr. Pearse was awarded to R. Bennett.

The names of the successful candidates were as follows:—

Practical Sanitary Science.

Patrick A. Cunningham,
Robert Edwin Hemmings,
John Lemm,
Arthur Poonoo Samy,

Sanitary Inspectors.

Romas Bennett,
George William Coysh,
Herbert John William Gidley,
Sidney Maurice Gidley,
John Thomas Longstaff,
George Morphew,
John Reidie,
William Henry Woolley.

QUESTIONS SET AT THE HONGKONG EXAMINATION

SANITARY SCIENCE EXAMINATION.—PAPER 1

Two hours allowed.

Question 1. State briefly the requirements an inlet ventilator should fulfil, and the position it should occupy in :—

- (*a*) A church.
- (*b*) An engineering workship with work benches arranged along the external walls.
- (*c*) A ward in a general hospital.

Question 2. What are the objections to the treatment of sewage on land by board irrigation? Sketch a sectional view of :—

- (*a*) A septic tank.
- (*b*) A bacteria bed, showing what you consider the best manner of admitting the sewage to each.

Question 3. What is meant by solution and suspension? Describe with a sketch of apparatus used the process by which pure water can be obtained from a naturally occurring water which contains other bodies both in suspension and solution.

Question 4. A lecture room for evening use is to be built in England, and it is determined to ventilate it by the natural system of ventilation. What point is it necessary to note before proceeding to plan the building, and what natural laws in physics are involved in the working of such a system of ventilation?

Question 5. Give the composition of an upland surface water, and how would you filter such water before distributing it in the mains?

Question 6. Give the composition and physical properties of air, and state briefly the principle of ventilation.

Question 7. How many cubic feet per second will be discharged by a pipe 12″ diameter × 1 mile long, with a head of 12 feet per mile?

$$\text{Formula: Discharge} = {\cdot}7854 \times 48 \times \sqrt{\frac{\text{diar. in ft.} \times \text{head in ft.}}{\text{length in ft.} + 54 \text{ diars. in ft.}}}$$

LOCAL CONDITIONS.

Question 8.—(*a*) How would you judge on works of the quality of lime being used?

(*b*) What is your experience of the effects of using fresh or sea water for mixing lime and red earth concrete?

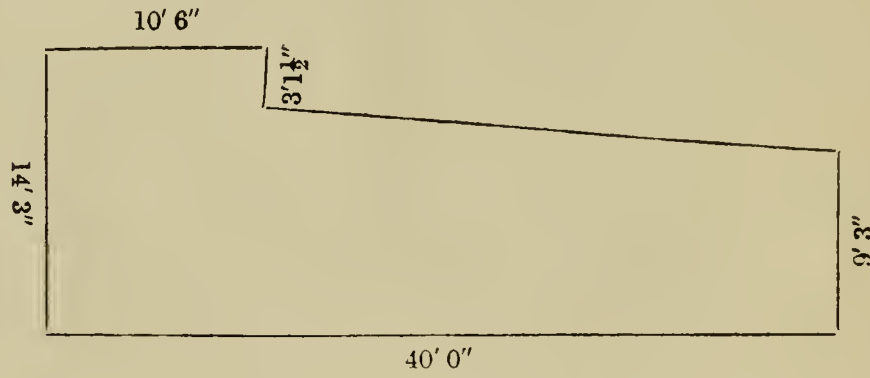
(*c*) In the case of a building being erected against a hill-side, what space must be left from the back of building and the toe of the slope of the hill-side, and in case of the soil being damp and impregnated with water what precautions must be taken?

SANITARY INSPECTORS EXAMINATION.

Question 1. Sketch the section of a surface well, showing what precautions are necessary to prevent contamination by sewage.

Question 2. Describe the appearance of pork affected with *Cysticerous Cellulosal* (measles).

Question 3. If a room be shaped as in accompanying diagram and 12′ 9″ high, what is the floor area and the cubic contents; and how many adults will be allowed to occupy, under the present Public Health Ordinance in Chinese districts?



Question 4. A house has been unoccupied and without water for a long time; on being called in to inspect the drains and plumbing, what would you do?

Question 5. Describe a Washington Lyon's disinfector. What is the difference between saturated and superheated steam, and what articles would you not disinfect by steam?

Question 6. What is the composition of the atmosphere, and how does it vary? In what ways is the air of a modern manufacturing city liable to pollution?

Question 7. State what you understand by the following expressions:

(1) External Air,
(2) Room,
(3) Cubicle,

and distinguish between a room and a cubicle. State also what conditions are necessary in order to make a cubicle, or cubicles, legal, altogether apart from any exemption being granted by the Governor in Council.

Question 8. What points would you direct your attention to in reporting on a surface well, and explain what steps you would take to render a surface well as safe a source of water supply as possible.

SYNOPSIS OF LECTURES BY FRANK BROWNE, PH. CH., F.C.S.

MECHANICAL PHYSICS.

Matter—atoms, molecules, liquids, solids, gases, forces.

Impenetrability—permeability, extension, porosity, compressibility, elasticity, inertia.

Mass—unit of mass, yard, density, relative density.

Attraction—weight, laws of falling bodies, acceleration of gravity, velocity, momentum, laws of motion.

Mechanical Powers (Machines)—lever, inclined plane, pulley, wheel and axle, wedge, screw, toothed wheels.

Work—power, energy, friction.

Molecular Forces—cohesion, adhesion, affinity.

Properties of Solids—tenacity, ductility, hardness.

Pascal's Law of Archimedes—hydrometer.

Capillarity—meniscus.

Syphon—air-pump, vacuum syphon pump.

Heat.—Nature, conversion, sources, conductors, transmission, conduction, radiation, effect of heat, latent heat, thermometers.

Light.—Nature, reflection, refraction, transmission, absorption, vibration, colour, primary colours, heat rays, chemical rays, effect of light.

Magnetism.—Nature, properties of lodestone, magnets, single and double touch.

Electricity.—Nature, attraction, repulsion, conductors, induction; kinds of electricity—frictional, voltaic, induced, D. Galvani's experiment, primary and secondary batteries, magneto electricity, conversion of electricity into magnetism and magnetism into electricity.

Chemistry.—Definition, chemical force, characteristics, affinity, indestructibility of matter, elements, metals, non-metals, chemical compound, mechanical mixture, atomic theory, law of definite proportions, of multiple proportion, of reciprocal proportions.

SYNOPSIS OF LECTURES BY DR. W. W. PEARSE, ACT. M.O.H., D.PH., M.B. ABERDEEN.

METEOROLOGY.

Extent of the Science.

Weather and Climate.

Influence of Climate on Race.

TEMPERATURE. — Thermometers: Fahrenheit and Centigrade, Maximum and Minimum.

MOISTURE AND HUMIDITY.—Hygrometers; wet and dry bulbs; absolute humidity, relative humidity.

ATMOSPHERIC PRESSURE.—Barometers, mercurial and aneroid barometers, variations of pressure, movement of the air, winds, trade winds, origin and direction, monsoons, revolving storms—cyclones, hurricanes and typhoons.

RAINFALL.—The rain gauge.

THE ATMOSPHERE.

ITS COMPOSITION.—Oxygen, nitrogen, carbondioxide, ozone, ammonia and other gases. Variability of composition. Organic matter and microbes. Dust and its usefulness in the atmosphere.

RESPIRATION.—Effect of animal and plant life on the atmosphere.

COMBUSTION.—Its effect on the atmosphere.

SOURCES OF POLLUTION.

SEWER GAS.—Fallacy in regard to.

MARSH AIR.—Relation to malaria.

GRAVEYARDS.—Their Effects.

MANUFACTURES.—Their various effects on the atmosphere and on health.

EXAMINATION OF AIR.—(1) Solid particles. (2) Micro-organisms. (3) Organic matter.

ESTIMATION OF CARBONIC ACID GAS (CO_2).—(1) Pettenkoffer's method. (2) Angus Smith's method.

ESTIMATION OF CARBONIC OXIDE (CO).

ESTIMATION OF OXYGEN (O_2).

ESTIMATION OF OZONE (O_3).

ESTIMATION OF AMMONIA (NH_3).

ESTIMATION OF NITROGEN (N_2).

ESTIMATION OF AQUEOUS VAPOUR.

VENTILATION.—Natural and artificial ventilation. Cubic space required. Movements of air—law regulating the Montgolfier formula.

AIR AND DISEASE.

AIR-BORNE INFECTION.

OLD AND NEW THEORIES.

INFECTION OF THE ATMOSPHERE BY THE BREATH.

EFFECTS OF BAD AIR.

OVERCROWDING AND ITS EFFECTS.—(1) Chronic. (2) Acute.

WATER.

Pure Water.

Natural Waters.—Sources:—rain water, river water, well water, spring water, ground water, lakes, sea water.

Water Supply.—Sources: (1) wells—(*a*) shallow, (*b*) deep; (2) springs; (3) streams; (4) rain; (5) lakes.

Differences in Composition due to Diffrent Sources.

Relative Values of Different Kinds of Water.

Hard and Soft Water.

Amount Required per Head.

Storage of Water.

Systems of Supply.—Constant and intermittent systems.

Purification and Filtration.—(1) In the large scale; (2) domestic.

Examination of Water.—Interpretation of results.

Water and Disease.

SOIL.

Physical and Chemical Characteristics.—Composition, porosity, permeability, temperature, moisture, gases.

Cultivation of Soil.—Nitrification, disinfectant power.

Soil and Disease.—Healthy and unhealthy sites for houses.

Specific Diseases in Relation to Soil.—Tetanus, anthrax, typhoid fever, diphtheria, cholera, diarrhœa, plague.

SEWAGE REMOVAL AND DISPOSAL.

Sewage.—Its meaning in the widest sense. Excreta—household waste water, rain water, trades waste. Excreta—amount per head—its nature and the changes it undergoes. Removal of excreta the chief problem, its relation to specific disease. Primitive methods of disposal. Action of the soil. Maintenance of the cycle of life. Effects of civilization—the congregation of men in villages and towns, places set spart for disposal of excreta, middens, dangers arising from these latter, pollution of wells and streams, L.G.B. rules *re* middens. Evolution of bucket system. Variations in bucket system—absorbent buckets, admixture of ashes, dry earth. Circumstances necessary for success of these methods—open spaces, availability of ashes and dry earth, market for disposal, means of easy transit. Invention of the water carriage system. Cesspits. Discharge into rivers and sea. First effects of this invention. Insanitary fitments. Pollution of rivers and estuaries.

Remedies.—Improved sanitary appliances and engineering treatment of sewage, chemical processes, biological processes, the sewage farm, the septic tank.

Removal and Disposal of Refuse.—Necessity of scavenging. Powers conferred by law *re* cleaning of streets and removal of refuse. Public Health Act, 1875—Sections 42 to 50. P. H. A. Amendment Act, 1890—Sections 25 to 27. P. H. London Act, 1891—Sections 29 to 36. Division of refuse into—(1) house or domestic refuse; (2) trade or manufactures refuse; (3) street sweepings. Composition of house refuse. Composition of street refuse. Collection of refuse—(1) from streets; (2) from houses; daily and weekly collection. Diposal of refuse—(1) of street sweepings, (2) of house refuse. Refuse tips. Dumping at sea. Refuse sorting. Destructors—the failure of early destructors, the success of modern destructors.

SYNOPSIS OF LECTURES BY MR. D. JAFFE, A.M.I.C.E.,

CALCULATIONS, MEASUREMENTS, AND THE INTERPRETATION OF PLANS AND SECTIONS TO SCALE.

Calculations.—The basis of all calculations a system of units. Description of the imperial system of units. The simplification of problems by reducing all the terms to a given system of units. The effect of an empirical constant in engineering problems. The importance of understanding that figures in engineering problems are not merely symbols, but have a definite meaning and refer to definite forces and actions. General simplification of all engineering problems.

Measurements.—Definition of the basis of all measurements and its application to practical measurements. Dimensions of one magnitude—how measured. The graphic representation of simple measurements, and the application of vectors to problems of velocity, force, stress, strain, etc. Measurements of the strength of materials—how made—and the importance of such measurements in engineering. Measurements of more than one dimension and their application to surveying.

The Interpretation of Plans and Sections to Scale.—The importance of referring all scales back to the fundamental units. How to express scales in terms of the fundamental units. Method of drawing plans and sections to scale. Construction of scales.

SYNOPSIS OF LECTURES BY MR GIBSON, C.V.S., M.R.C.V.S.,

MEAT INSPECTION.

Introductory Remarks.—Method of examining animals and complete carcases:—

1.—Inspection of Live Animals.—*(a)* condition; *(b)* age; *(c)* sex; *(d)* temperature; *(e)* symptoms of disease; *(f)* injuries.

2.—-Inspection during Slaughter.—*(a)* bleeding; *(b)* sulcutaneous tissues; *(c)* udder; *(d)* organs.

3.—Inspection after Slaughter.—*(a)* examination of organs, organs are best examined immediately after removal; *(b)* examination of flesh; importance of always using a sharp knife; *(c)* points to be considered in forming an opinion.

4.—Specific Diseases.

Inflammatory Diseases.—Pneumonia (inflammation of lungs). Pleurisy (inflammation of pleuro). Peritonitis (inflammation of peritoneum). Pericarditis (inflammation of kidneys).

Inspection of Meat in Inflammatory Diseases.—Blood diseases, red water.

Bacterial Diseases:—Tuberculosis—lungs, pleuro, heart, liver, spleen, stomach, bowels, kidneys, uterus and ovaries, mammary glands, brain, bones, muscle. Glanders—spleen, intestines, kidneys, skin. Suppurations—abscesses, navel ill or septic omphalitis, spetic metritis, swine fever, hog cholera, contagious pleuro, pneumonia, foot and mouth disease, rinderpest, anthrax, black quarter, tetanus, ratres.

Parasitic Diseases:—Worms—*cestodes* tape worms, *trematodes*, *nematodes*, round worms, mange.

SYNOPSIS OF LECTURES BY CAPT. FITZWILLIAMS, A.S.C.

Characteristics of Meat.—(1) Appearance good—(*a*) fresh, (*b*) fat, (*c*) bone. (2) bad; (3) disease; (4) glands.

Discriptions of ox, cow, heifer, bull, mutton.

Age, teeth—horse, goat.

Comparisions, &c.

Description of (1) milk—tests, adulteration, specific gravity; (2) butter, tests—margarine or butterine, preparation of, laws; (3) tea; (4) coffee; (5) sugar; (6) salt; (7) flour—(*a*) disease, (*b*) insects, (*c*) preparation, (*d*) testing,

Laws.—Nuisance Removal Act, Clauses II. and III. Public Health Act, 1875, Clauses 116, 117, 118, 119.

SYNOPSIS OF LECTURES BY MR. J. J. BRYAN.

SANITARY PLUMBING.

MATERIALS—action of air and water on.

WATER CLOSETS:—Situation, lighting and ventilation of the compartment, general principles, form of basin, seal of trap, pan closet, long hopper closet valve closet, wash-out closet, wash-down closet, syphonic closet, pedestal closet, slop closet and trough closets.

TRAPS:—Lead, earthenware, D, anti D; S, and P, mechanical, syphonage of, loss of seal by evaporation, capillary attraction, anti-syphonage pipes.

FLUSHING CISTERNS:—Water-waste preventers, height of cistern from fitting, size of supply pipe.

SOIL PIPES:—Drawn lead, seamed lead, iron, table of weights, position of, fixing of, junction of, ventilation of.

JOINTS:—Wiped joint, lead and iron, earthenware and lead, earthenware and iron, keramic joint, flange joint.

SLOP SINKS, URINALS, BATHS, SINKS, LAVATORY BASINS—material of, position of, fixing of, trapping of, overflow and waste pipes of.

HOUSE INSPECTION:—General notes, routine of inspection, internal sanitary fittings, outside drainage.

PRACTICAL VENTILATION

By ARTHUR H. OUGH, A.R.I.B.A.

Assoc. M. Inst. C. E.

VENTILATION is the term applied to the operation of providing a supply of air of sufficient quantity, in proper condition as to temperature, humidity, and purity, distributed to the inmates of a building in such a manner as to maintain them in a state of health and vigour, without causing discomfort.

The quantity should be sufficient to prevent any sensation of closeness or stuffiness by a person entering the building from the outer air.

The standard of purity is gauged by the amount of carbonic acid gas contained, which should not exceed 0.04 per cent.

By this standard it is found that the following amounts of air are required by persons in a state of repose.

	Cubic feet of fresh air per head per hour.	Cubic space required in cold weather.	
		Unwarmed air if changed 3 times per hour.	Air at 58° to 60° F. changed ten times per hour.
Adult males	3,600	1,200	360
Adult females ...	3,000	1,000	300
Children	2,000	666	200
Assemblages of the above	3,000	1,000	300

Smaller quantities will be required where rooms are occupied for short periods only, such as one or two hours, as in schools or churches.

TABLE OF AIR SPACE PROVIDED BY VARIOUS AUTHORITIES.

	Cubic Feet.	Per
London School Board	150	Scholar
Common Lodging Houses	300	Person
Factories and Workhouses { Day	250	do.
Factories and Workhouses { Night	400	
Barracks	600	Man
Army Hospital Wards	1,200	Patient
Other Hospitals	2,000	do.
Dwellings	1,000	Person

The temperature at which fresh air is supplied should vary with the speed at which it travels: at a temperature of 50° F. it should not exceed 5 ft. per second, while lower temperatures require less velocity down to 2 ft. or even 1 ft. per second at 35° F. Many persons will feel uncomfortable, or what is known as "in a draught," if exposed to a current of air travelling at more than 1 ft. per second at a temperature of 60° F.

An ordinary fire causes a draught of 3 to 4 ft. per second; a strong fire 6 ft. per second.

TABLE SHOWING RELATION OF TEMPERATURE TO VELOCITY.

Temperature Fahr.	Max. Velocity in feet per second.
35°	1
38°	2
42°	3
46°	4
50°	5

People cannot sit for a long time with impunity in air having a temperature below 50° F. even when there is scarcely any perceptible current, unless the loss of heat from the surface of their bodies is prevented by exceptionally warm clothing, or the counteracting influence of radiant heat.

During the colder months the incoming air should be warmed to near 60° F. for all buildings occupied for more than an hour at a time, and where the floor space per head is less than 16 square ft. Otherwise a sufficient quantity of air cannot be provided without causing intolerable draughts.

The humidity should not exceed 74°/$_0$ and coarse dust should be removed by screens; fine dust can only be removed by expensive apparatus, and in ordinary buildings fitted with doors and windows that are not actually air tight it is not taken into account.

The air in which we live always contains aqueous vapour. When the density of this vapour approaches the maximum for the existing temperature, we feel a sense of oppression, and a slight exertion suffices to throw us into a sensible perspiration. On the other hand, when the ratio of the actual to the maximum density is unusually small, evaporation takes place with excessive rapidity, rendering the skin dry and liable tocrack or peel off.

The ratio of the actual to the maximum density of vapour, or, what is the same thing, the ratio of the actual to the maximum pressure of vapour, is called the humidity, or the relative humidity, of the air. It is usually expressed as a percentage. For example "humidity 75°/$_0$" means that the quantity of vapour present in a given space is three-quarters of the greatest quantity that could exist in that space at the actual temperature.

The air should be properly distributed principally to the mouths and nostrils of the persons, that is, at about the level of the head when seated, or four feet from the floor, and diffused on entering, avoiding columns or jets of air with stagnant portions intervening.

Three useful points to be remembered are:—

1. Cold air falls.
2. Foul air (*i.e.* air charged with carbonic acid gas) also falls.
3. Warm air rises.

In temperate climates the interior air of any building is usually of a higher temperature than that outside, consequently on opening a door or window and admitting cold air it immediately finds its way to the floor, and makes itself felt about the feet of the occupants. The warm air that is displaced, being lighter than the entering cold air, finds its way out of the same opening—that is provided there is but one.

This can be demonstrated by holding a lighted taper, first in the lower part of the door, when the flame will be drawn inwards, and then in the upper part, where it will be drawn in the opposite direction.

Warm air being lighter than cold, rises, but rapidly loses its heat and again falls, being assisted in the downward direction by the carbonic acid gas from the breath and bodies of the occupants.

For example.—A number of people enter a building such as a church that is full of cold air; they warm and vitiate a certain quantity which rises till cooled by the upper air in the building; it then falls upon their heads in currents of appreciable coolness, causing many to suspect that windows are open above them. On inspection they find that no windows are open, but nevertheless they feel draughts. These draughts are not imaginary, they are there, and continue till the whole of the air in the building gets warmed up by the heat given off by the congregation. Some people aver that the danger of catching cold prevents them from entering such places. It would be better perhaps if they took steps to get them properly warmed by artificial means before the time appointed for admitting the congregation.

Natural ventilation depends for its success upon the difference in temperature between the interior and exterior of the building treated. So long as the interior remains at a higher temperature than the outside air, the latter will continue to flow in through any openings that may exist. The upper part of a room full of people becomes heated, sometimes to an extent that will produce extreme discomfort to any one raised considerably above the rest, but so long as the people on the floor are provided with sufficient fresh air, this upper stratum may be neglected for practical purposes.

It is a mistake in natural ventilation to provide openings in the ceiling or high up in the walls for the purpose of allowing the foul air to escape; for unless artificial means be employed to *draw* it out, it will *not* escape, but cold air will enter by these openings and fall in the form of draughts. Do not be deceived by the little arrows on the diagrams supplied by makers of ventilators: air often refuses to travel in the way indicated. Bear in mind that all systems of natural ventilation must at some time or other be reversed. Incoming air may also be "short circuited," *i.e.* pass direct from inlet to outlet in a small column or sheet, producing a strong draught in its course, and leaving large spaces altogether unventilated. It is a common experience with exhaust systems to find the inlets permanently closed, mostly by being papered over, the inmates preferring to endure the effects of foul atmosphere, or to obtain relief by opening doors or windows.

The chief difficulties in the way of natural ventilation (*i.e.* outlet by fireplace, inlet by open window, TOBIN tubes, HINCKE's sash inlet, &c.) are (1) the prevention of down draughts from the inlets, and the cold floor current; (2) the even distribution of the fresh air at the level where it is most wanted, viz., at the faces of the occupants. Less draught is felt from widely opened windows than from partially opened ones.

No ventilator exists that will *create* an air current without aid of fan or heat. The so called air pump ventilators will not pump in a calm, and an open pipe will extract quite as well as the most expensive fixed cowl advertised, *provided a wind is blowing across the end of it.* All cowls that will allow air to escape, will also admit it. On a still cold day cold air will soak in and fall into and through the hot air that is supposed to be going out. Flaps to prevent down draught are liable to stick; those controlled by a cord do the same, moreover the cords break. How often do we see a SHERRINGHAM or ARNOTT ventilator with no cord, and permanently stuck open or shut! When attempting natural ventilation avoid outlets, but look after the inlets and provide plenty of them. Place them so that they can pass air either as outlets or inlets as the case may be, without causing draught. The best place for an inlet is in the wall anywhere between 2 ft. and 5 ft. from the floor and under a window; because here the opening does not cut into and weaken a pier, also it delivers air about the level of a person sitting, and is easily accessible. On no account should it be placed in the floor. It should be capable of being opened much or little, or closed entirely so as to control the supply or air; it should exclude rain, dust, and thieves, and be easily opened up for cleaning, also it should diffuse the air immediately on entering, not direct it into the building in a solid column like a hose. And most important of all it should be of ample area. For example.—Take a room 10 ft. square and 10 ft. high; this contains 10′ × 10′ × 10′=1,000 cubic feet. This air should be changed four times per hour; therefore an inlet will be required to pass 4,000 feet per hour. Now at a velocity of 5 ft. per second, one square foot of area will pass 60 m. × 60 s. × 5′=18,000; therefore the inlet must have a net area of $\frac{4,000}{18,000}$ feet, or striking out the 000, $\frac{4}{18}$ feet or 32 square inches. An ordinary air brick has a net area of about half its total area, so for this inlet one will be required having 64 square inches or about 8″ × 8″. Now if the same room be occupied by four persons each using five cubic feet of air per minute while at rest, a fire using five feet per minute, and a gas jet using another five feet per minute, we have to provide 6 × 5 ft. × 60 m.=1,800 feet per hour; but the inlet is capable of passing 4,000 feet so there is ample margin. This margin is necessary because we cannot be sure that the velocity of the entering air will always be five feet per second. It may fall to half that speed, and at times the current may be reversed, so that it is usual to calculate on changing the entire contents three or more times per hour, according to the use to which the room is put.

The action of moving external air or wind upon openings varies according to the direction in which it approaches. Thus—blowing directly into the opening it enters; blowing obliquely into the opening it takes a rotary motion, part enters and part returns, bringing with it some of the internal air. Blowing past or at right angles to the axis of the opening it exhausts. For example.—The "torpedo" ventilator used on railway carriages was originally intended to be run head to wind, the air divided by the point of the travelling cone setting up a suction and exhausting the internal air from the carriage. This was not found to be the case in practice, for the current set up caused an eddy and down draught mingled with cinders, etc., from the locomotive. The torpedo was then turned broadside to wind and worked successfully; but apart from the protection from dirt afforded by the cones, a plain T headed pipe with open ends would exhaust equally well. Every building must be considered solely on its own merits; any attempt to fit a building to a "system," instead of "system" to a building is bound to end in failure. The position of the building in the street, the position of the street with regard to the prevailing winds and the points of the compass, the height of the surrounding houses, ground swirl and suction must all be taken into consideration. The larger the aperture of the shaft inlets, the more violent will be the wind effects. Much stress is laid by experts upon the removal of contaminated air. I do not think from my own experience that this is of such vital importance as many of them allege, especially when natural ventilation is employed. At the headquarters of the Royal Corinthian Yacht Club there is a large dining-room designed to seat about one hundred. The room has inlet ventilators only, on two sides under the windows. On the occasion of the opening dinner, the proceedings developed into a very smoky smoking concert, at which some two hundred people, nearly all smoking, were crowded into the room. I observed that the smoke hung thickly in the upper part of the room as far down as 7 ft. from the floor, below which level the air was quiet clear and pure. I attributed this to the fact that I had put in two large flues in the ceiling, and congratulated myself that they were carrying off as much smoke and foul air as was necessary. No windows were open, and the inlets were working satisfactorily.

To my surprise, on examining the valves in the "outlet" flues, I found them closed, and they were closed the whole evening.

The "inlets" therefore had been doing all the work, some acting as outlets, and they had kept the lower stratum of air in the room perfectly fresh in spite of the fact that no outlet in the upper part was working.

If we supply fresh air in sufficient quantity it will drive out the foul air, or so mingle with it that it becomes fit to breathe. No doubt the foul air goes somewhere, and seldom up the outlets provided for it. My experience shows that it goes out of the inlets, either by sharing them with the incoming air, as in the experiment of the open door, or by reversing the current in some of them. The only method that can be absolutely depended upon for the extraction of foul air is that of propelling or pumping it by mechanical means, or by employing heat to induce an upward current in the exhaust flue.

I will now briefly describe some of the contrivances designed to control the admission and extraction of air, and point out their respective advantages and disadvantages.

COMBINED SMOKE AND AIR FLUE.—Intended to be built into chimney breasts.

THE ACME EXHAUST LOUVRE VENTILATOR.—The air current or wind strikes upon curved plates and is curled over and out again, drawing the internal air with it. It is claimed that this device prevents down draught. It probably does in a wind, but in calm cold weather the air will soak in and fall causing draught.

ARCHIMEDEAN EXHAUST COWL—has a large number of blades or paddles set round a cylindrical frame, with spaces between. These cause the cowl to revolve, turning an Archimedean screw contained in the flue, which creates an exhaust. They are very expensive, and require constant attention, oiling, and cleaning, otherwise they stick and cause down draughts.

ARNOTT'S MICA FLAP OUTLET—consists of a frame built into the smoke flue, carrying balanced flaps of mica or silk which act as valves, opening to allow foul air to be drawn into the flue by the ascending heat from the fire, and closing against any back draught. From its position in a branch of the flue it soon becomes clogged with soot, puffs of air that are not strong enough to close the flaps yet which carry smoke with them enter the room, the soot collects round the ventilator, disfiguring the wall and ceiling, and the whole thing is generally carefully papered over by the next decorator that is called in.

BLACKMAN AIR PROPELLER—consists of a number of fans (usually 8) radiating from a boss or hub, with a strengthening ring of metal rivetted to their outer edges. The fans or blades are so bent, especially towards the periphery, that the air is attracted or drawn into the whole of the supply service, about 40 per cent. entering around the periphery, and 60 per cent. on the side. All the air is propelled directly forward from the discharge side of the propeller with little friction or waste of power. A 48 in. propeller has a surface of 12 square ft. and when driven at the rate of 350 revolutions per minute will move 15,000 cubic ft. of air per minute, at a velocity of 20 ft. per second, requiring about one horse power. Blowers such as ROOT'S, BAKER'S, &c. are made for producing a blast having a positive force, distinguished from a fan, which does not produce pressure. A blower must have an outlet or the machine stops, while a fan can run with the outlet obstructed or entirely closed without being in the least impeded. Blowers are not used for ventilation, so are only mentioned here in passing.

BOYLE'S AIR PUMP—contains a number of curved baffle plates which deflect the wind and turn it out again, setting up an exhaust proportionate to the strength of the wind. There is very little, if any, more power exerted than is got by the same wind blowing across the top of an open pipe, and it is liable to reverse in a calm. Admirers of this form of extractor state that at certain altitudes from the ground, such as the top of a building, the air is always in motion. My own experience does not support this, especially on still, frosty, or foggy nights when the cold air easily overcomes by its own weight any exhaust set up by the baffles, and pours down into the warmer air of the building.

CENTRIFUGAL FANS—generally consist of a central spindle upon which are hung four or six arms meeting in the centre; upon each arm is a blade for propelling the air. The whole is cased in a round box, fitted to the blades, having openings on each side about the spindle for the admission of air, and one in the circumference for its delivery to the flue.

ELLISON'S CONICAL INLET—is an air brick with horizontal conical holes fixed with the small end outward. It is claimed that these diffuse the air. They are usually fixed too high, with the objection of draught near the wall. Another inlet on the same principle has the holes all inclined upwards, and contains an air filter of wire and cotton suspended in the vertical pipe. It is controlled by a valve as TOBIN'S, is not easy to clean, and the valves stick. It also causes draughts near the wall.

ELLISON'S DRAWER INLET—has a square box containing crossed plates behind a face plate that can be pulled in and out like a drawer, the entering column of air being divided into four and deflected by the face plate up, down, and sideways. This ventilator fulfils nearly all the requirements of a perfect inlet. It deflects the air in all directions, is under control, can be got at for adjustment and cleaning, and has a screen or filter for excluding dust. Its drawbacks are—the face plate is not large enough, consequently the air gets sent forward into the room in too great volume, and is not *diffused;* it holds dirt and is a most convenient receptacle for rubbish, and is liable to stick in damp weather.

HENMAN'S INLET—consists of a light cast-iron box with parallel sides, the outer face pierced for the admission of air, the bottom and inner face suitably curved, and the top partly open. A talc flap is suspended within, so that when it hangs vertically there is a space between the lower edge of the flap and the surrounding box, equal to about one-third of a superficial foot. The flap is regulated to remain vertical until the velocity of the air passing through exceeds 10 ft. per second; but when that velocity is exceeded the flap becomes deflected upwards, the lower edge is brought nearer to the inner curve of the box proportionately to the velocity of the air passing through, so that the area of the aperture becomes reduced, and the inflow is maintained at a practically uniform rate, whatever may be the force of the wind outside. Automatic regulation is the leading principle of the appliance, but to further reduce the velocity of the incoming air and diffuse it throughout the apartment, a panel of radiated louvres is fixed at the inlet, opening flush with the inner face of the wall.

Advantages.—It controls the air supply automatically, and is noiseless so long as the bearings do not squeak or wear loose and rattle.

Disadvantages—It has moveable parts that are likely to get out of order. It is not easily cleaned from inside. It cannot be closed from inside. It does not diffuse the air sufficiently. It cuts away a great deal of the wall and is expensive to fix. The talc flap is liable to curl up and cease to act.

HINCKE'S WINDOW BAR—is simply a wire screen fixed temporarily under the lower sash, admitting air there and also at the meeting rail. A solid board does quite as well, and the raised inner bottom bead, occasionally seen in some of our older hospitals, is on the same principle. It has all the advantages and disadvantages of an open window.

AN EXHAUST VENTILATOR (or smoky chimney preventer)—designed by MR. R. K. LEIGH, M.I.C.E., works on the principle of a steam injector, and consists of an outer and inner cone pivoted upon the top of the flue. The larger end will, in revolving, remain to leeward, exposing the smaller end to the force of the wind. The wind entering at the small end rushes through the interior cone, setting up a strong exhausting action across the head of the vertical flue. The whole thing revolves on a centre pivot, and is simple and strong. It is open to the usual disadvantage of revolving cowls—that of sticking, and will not exhaust unless there is a wind blowing. It is also liable to admit cold air in still weather. As a cure for smoky chimneys it should prove valuable, as it effectually stops all downward puffs.

LOBSTER BACK REVOLVING COWL.—This is simply a right-angled bend revolving on the top of the exhaust flue. The vane causes it to keep its back to the wind, it does not exhaust strongly, and is liable to stick and cause down draught.

MACKINNELL'S VENTILATOR—consists of an outer and inner tube with conical cap over the inner one. It is claimed that the wind striking the inner tube above the outer one, is deflected downwards into the room, causing a pressure which forces the foul air upwards through the inner tube, while the cone excludes rain and down draught. If this is so, what is the entering air but a down draught? It may work when the wind is blowing, but in a calm cold air will enter by both tubes and fall in a most unpleasant way.

THE OFFA VENTILATOR—has a frame with sliding pins, carrying a face plate considerably larger than the opening, which slides in and out in a similar way to ELLISON'S DRAWER INLET, but without the crossed plates. It can be opened to give a periphery area at edge of face plate equal to the area of the opening, or as much less as is required, enabling the current to be controlled to a nicety, or closed altogether. It carries a cotton sponge cloth filter that can be renewed in a minute without removing the face plate. The entering column of air, on striking the face plate, is so broken up and diffused in all directions that it soaks into the room and all forward draught is stopped ; dust falls straight through and has no place to lodge. The whole of the interior is accessible from the room without taking to pieces, and it can be fixed at the bed head in hospitals without danger of draught to the patient. It should be fixed about 2 ft. from the floor. A great advantage in this pattern is that it can be set to work as an exhaust when the wind blows strongly against or past it from the outside, and admits air during lulls so long as the temperature inside the room is higher than that outside. I have made many practical tests with this contrivance, one of which will be useful to describe here.

At Messrs. Huntley & Palmers' Biscuit Factory, one of the hottest bakeries is that where sugar wafers are made. The bakery contains a number of small ovens ranged along the walls, with the men working within 2 ft. of the wall and exposed to great heat—the thermometer at 6 ft. from the ground being frequently 120° F. Two large fans were used to exhaust the air from the roof, with the result that strong draughts were set up at all the doors and windows, bringing in dust from outside and even flour from the adjoining store. These were highly dangerous to men working in such a temperature. A row of OFFA ventilators was put in all along one wall immediately behind the men and 6 in. above the floor, each ventilator being about 2 ft. 6 in. by 1 ft. 6 in. The face plates were set 2 in. to 2½ in. out from the wall and the fans stopped. The great heat of the bakery caused air to rush in through the ventilators, which was immediately diffused by the face plates all over the wall. The men felt no draught and got the air where they wanted it; the temperature was easily maintained at 60° by adjusting the amount of air admitted, and the fans were finally done away with. The system proved a success and has continued so without alteration for the last eight years. No special outlets were provided for the hot air; but it was found that certain of the inlets acted as outlets according to the conditions prevailing outside.

SHERRINGHAM'S INLET—has a flap with hopper sides hinged at bottom to drop in ; it is closed by a cord and weight. When open it delivers a jet of air upwards and outwards, causing a perceptible draught. Improvements on this form introduce a screen for cleaning the air ; but as it is usually fixed high up in the wall, it is not easily accessible, and the screens are rarely changed, eventually becoming blocked altogether. The cord breaks and, sad to relate, is seldom renewed, the inlet remaining permanently closed.

THE LETTER BOX VENTILATOR—is on the same principle, but is fixed open, usually over a door. People who write upon the subject of cottage architecture generally recommend this form on account of cheapness. This is its sole beauty.

TOBIN'S TUBE—is a vertical pipe fixed on inside of room with an elbow at bottom communicating with the outer air. It is generally about 8 in. × 4 in. and from 1 ft. 6 in. to 4 ft. high, at top, from the floor. The air enters in a fountain vertically against the wall, strikes the cold surface and falls over the inmates in a shower. It is closed by a disc valve, and is efficient so far as it goes, but is very expensive when enough tubes are put in to provide the necessary capacity. Its great financial success is due to the fact of its being placed on the market at a time when the whole nation was suddenly awakened by the serious illness of our King, then Prince of Wales, to the necessity of considering the question of healthy dwellings. A leading article in *The Times* was written about this particular contrivance, and the inventor's fortune was made. Air filters have been added in the shape of a conical bag suspended in the pipe. Its disadvantages are the small size of the stream of air admitted, the concentration and fountain-like shape of the current, the difficulty of cleansing, and sticking of the valve. Strong down draughts are caused close to the walls, making it unsuitable for use in ball-rooms, churches, and the like.

THE VORTICONE INLET—is made of terra-cotta with its inner face "screw" or "spiral" shaped, and imparts a twisting and expanding motion to the entering current. It is simply impossible to clean and causes down draught, because it does not diffuse the air. The spiral motion is not perceptible to the person suffering from the down draught under it. The threads of the screw also collect dirt, which gets blown into the room by the stronger gusts.

The Select Committee appointed to enquire into the ventilation of the House of Commons has recently published its report, from which I quote.—"The arrangements for the ventilating of the Debating Chamber, with the Division Lobbies, etc., are briefly these:—Air is drawn in by a fan in the basement from the Terrace at the level of the ground. After being washed, cooled, or heated according to circumstances, and in times of fog passed through a cotton-wool filter, it is driven through gratings in the floor of the House, and rises to the ceiling. Thence by means of exhaust furnaces it is drawn into a shaft over the Commons' Lobby, and also through four pull down shafts, to the base of the Clock Tower up which it is discharged. Experiments showed that the air of the chamber when half full (it will hold 691 persons seated) contained about 4 volumes of CO_2 per 10,000. The mean temperature is usually about 62° F., while the humidity varies from 60°/₀ to 72°/₀. As to supply, the observations made show that the quantity generally exceeds 50 cub. ft. per head, but there is reason to think that present arrangements do not provide an adequate margin for a very crowded house."

From the foregoing the Committee conclude that the quality of the air supplied is satisfactory. This however is not confirmed by Members own feelings. It is a common experience that the air lacks freshness, and causes a feeling of lassitude and heaviness; moreover the air in passing through the floor gratings becomes *laden with dust.*

The recommendations of the Committee may be thus summarised:

1. The substitution of electric fans for the exhaust furnaces.
2. The simplification of the inlet passage and provision for its more thorough cleaning.
3. The use of water screens in place of the water spray.
4. The adoption of a more powerful and improved intake fan.
5. The introduction of the air beneath the seats.
6. The more frequent cleansing of the floor matting.

It will also be seen that the galleries are unprovided for. This appears to have been overlooked by the Committee. No provision of fresh air is made for these, and the occupants of the galleries only get second hand air after it has been vitiated by those on the floor of the House. The absence of proper distribution is well marked in this system; the whole column is short circuited and passes straight from floor to ceiling, leaving the portion by the seats stagnant. Of the systems suggested for properly ventilating the House of Commons, the PLENUM, and the EXHAUST seem, by the process of elimination, to be the two from which one is to be selected and applied.

By the PLENUM system the air is taken from the purest available source, filtered, washed, warmed or cooled as desired. It is then driven by fans through ducts, generally placed in the basement, and from these conveyed by up-cast shafts and discharged about 7 ft. 6 in. above the floor through louvres fixed at an angle of 40 degrees, so that the air impinges on the ceiling and flows across to the opposite wall (in theory). It then descends, returns across the room to the foot of the wall by which it entered, and is here forced into outlets at the floor level. These outlets are connected to shafts which ascend through the building and discharge the air at some height above the roof.

The advantages claimed for the PLENUM system are:—

1. The purest air available is supplied.
2. The air is distributed to all parts of the room.
3. It can be changed ten times an hour without producing draught.
4. All vitiated air can be driven out.
5. Efficiency is secured independently and in any weather.

Some of the disadvantages are (neglecting any consideration of expense):—

1. Long and numerous flues which become foul and pollute the air.

2. The dependence of the whole and every part of the system upon individual intelligence, care, and vigilance, and consequent liability to occasional failure and even complete breakdown.
3. Doors cannot be left open longer than necessary for entrance or exit, without upsetting the calculations of the person in charge of the fans—a great objection at Division.
4. There is no control over the outgoing air, and if, as the name PLENUM implies, the building is kept full and overflowing with air, there must be sufficient pressure to overcome the weight of the air in the outlet flues. This pressure is responsible for the feeling of stuffiness complained of, which is a mild form of the ill effects experienced by men in the Navy when working in forced draught.

By the EXHAUST OR VACUUM system the air is extracted through outlets at about 8 ft. from the floor, connected to a flue which leads to the bottom of a very high shaft. The air is propelled up this shaft by powerful fans. Air is admitted from outside through hot water coils; but it is also drawn in through every available crevice, some of which may admit impure air from objectionable sources. Another disadvantage in the EXHAUST system is experienced in buildings having only one upcast shaft, the rooms most remote from it getting scarcely any current. In many cases intolerable draughts are set up at the inlets, which are promptly closed, and relief is sought by opening doors, thus drawing in air from corridors, which passes direct to the outlets leaving large areas unventilated.

PLANNING AND CONSTRUCTION OF HOUSES

Primitive man lived in a cave, the entrance stopped with brushwood. Sometimes a hole in the roof communicated with the surface of the ground above; if not, smoke escaped by the entrance. Later he constructed a hut of wattle and mud with a hole in the roof and a door; smoke escaped by the hole in the roof, fresh air entered the same way, when it could, also by the door. Later he added windows for purposes of light, covered with parchment; smoke still escaped by the hole in the roof and continued to do so long after men had taken to building more substantially. After the introduction of glass no provision was made for ventilation other than by doors and windows. The fireplace was closed in and flue formed, slightly improving matters. It was left for the nineteenth century to devise special means of changing the air. Even at the present day cost is considered closely, with the result that little or nothing is spent on ventilation pure and simple.

In planning detached buildings, *i.e.* where light and air can be obtained all round, the chief considerations are:—

1. Aspect.
2. The direction of the prevailing wind.

By aspect is meant the position of the various parts of the building with regard to the points of the compass. Here in the tropics our chief aim is to get whatever shade we can for our bedrooms, placing the living rooms on the sunny side and protecting them by verandahs; but in temperate climates the sun is to be made the most of, so we put the bedrooms facing south-east to get the morning sun, the drawing-room south or south-west, and the dining and billiard-rooms on the north or north-east, as they are used principally at night. The library should have a north or north-west aspect. The larder, kitchen and offices are better on the north side, and the staircase next the west wall. It is important to have a well-lighted staircase and one that is easily warmed, so the east wind is to be avoided, as staircase windows are large and exercise a considerable influence on the warmth of the house. The prevailing wind has to be studied in arranging for natural ventilation, and shelter for windows on that side provided for.

The ideal house is one where windows can be kept open for the greater part of the year—this depends upon the planning of the windows. The prevailing wind must not be forgotten in laying out roads, especially at places on the coast, so that it should not be able to howl along the roads, but be broken up and made to circulate among the houses, providing them with air and not wasting its force in carrying along clouds of dust or wrecking gardens. The chief point aimed at here (Hongkong) is to get a current of air right through the house, and where so many back on to the hill side, as in the City of Victoria, this is only accomplished by leaving ample space between the face of the hill and the back of the houses. It will be observed that the breeze generally follows the depressions, *i.e.* blows up the valleys and nullahs, and in the hottest weather there is often a slight movement of the air in these places, while elsewhere it is quite still and oppressive. At the same time land is so valuable that we cannot afford to build only in the valleys, so it becomes necessary to consider how sufficient circulation of air can be obtained about the houses without sacrificing space. In laying out a city upon a steep hill side, it is usual to make the main roads follow the contour of the hill side, in order to keep them fairly level, not absolutely level, but with easy gradients for drainage, and with steeper cross streets giving the necessary communication from one main road to another. This arrangement gives convenient level frontages to the houses and provides that at least one side shall be exposed to the light and air. The cross streets should be laid out at short intervals, and where this is not possible the houses should not be built in solid rows, but should be semi-detached, at any rate so far as the floors above the ground floor are concerned. Unfortunately the man who builds a house seldom lives in it; the dwellings of the people the world over are built as a commercial speculation, at the lowest possible cost consistent with the observance of the various regulations enforced by the authorities. The regulations provide a minimum standard which is regarded by the builder as a maximum, with the result that a sort of stock pattern is arrived at, to which the inmates of the house have to fit themselves as best they may.

In the planning of cottages for agricultural labourers no special difficulties arise with regard to ventilation. They are usually detached or semi-detached, and so long as sufficient accommodation is provided can easily be kept healthy. One living room as large as possible is sufficient, with a light kitchen and large larder; a washing copper and sink with covered way for access in wet weather can be conveniently arranged outside under an open shed. One bedroom for the parents and one each for girls and boys are necessary. The staircase should be capable of passing a coffin, a point frequently neglected and most important, and it should be next an external wall. Every room should have a fire-place, and the relative positions of the bed and door should be studied. Town dwellers live and work at higher pressure; their eyes are fatigued with gazing upon bricks and mortar; their ears worried with strident sounds; and their feet wearied by the unyielding nature of the pavements upon which they walk. Land is valuable; the number of persons per acre is large; the air is not so pure; and under the very best conditions the health of the people suffers from the mere absence of green trees and grass, sunshine and restful surroundings.

The various types of workmen's dwellings are, as a rule, the result of local conditions. In the smaller county towns it is possible to design terraces of houses containing only living and bedrooms, and with their sanitary and washing arrangements detached and serving several houses, because the tenants are more permanent, remaining in the same district longer than those in the cities, consequently combined washhouses are often successful. On the other hand, in dealing with a migratory and less sociable population, such as is found in large cities, each dwelling must be complete in itself. Rents are so high that many families cannot afford to take a whole house. Even should one family do so, the upper floor is often sub-let. A house of this kind should have a living room and three bedrooms on each floor, with a separate kitchen fitted with a sink. A W.C. can be arranged on each floor, but it is preferable to keep these away from the house; if attached they should be over one another for convenience of drainage and water supply. The staircase should be placed next the outer wall and be well lighted. This necessitates a semi-detached house, and there can be no doubt that this plan is the proper one. A small ventilated food cupboard is required as this class of people seldom keep any stock of provisions. Saving of expense is the first consideration with those who are responsible for the rows of monotonous houses, described by one of our modern novelists as presenting the appearance of a "long wall with holes in it," but the question of cost, happily, is beyond the scope of this lecture, which deals with some of the principles of good design, and must necessarily be confined to generalities.

In this Colony we have a population in the City of Victoria which averages 132 persons per acre, and which when compared with—

	Persons per Acre	Death rate per 1,000
London	57.1	20.6
Liverpool	98.6	24.7
Plymouth	58.3	18.8
Bolton	48.4	22.8
Manchester	40.0	23.8
Salford	38.9	24.6
Average	56.88	22.55

appears and is enormous—the average death rate, 23 per thousand, being a much smaller ratio to the number of persons per acre than the average of the above six cities (*i.e.* as 23 is to 132 so 22 is to 56). Salford, it will be seen, has the highest death rate compared to the population per acre of any of these cities, and this is attributed to the large proportion of back to back houses existing there.

In Hongkong we have also a large number of back to back houses, that is to say houses which front upon a street, often narrow, and have a back wall which forms the party wall between them and similar houses in the next street. In some cases a yard is left in rear of the house, about 10 ft. wide, into which windows open; but by reason of there being no communication on the ground floor between this yard and the street, to allow of air circulation, the air therein is stagnant. In another type of back to back house, a scavenging lane is left between the two properties, which makes for improvement, but is still unsatisfactory, because the lanes cannot be laid out continuously, and the air currents are so frequently interrupted. The points that suggest themselves in planning dwellings for the class of people who inhabit these houses are as follows, viz., the provision of—

1. A common kitchen with separate cooking ranges, one for each floor, and each arranged to lock up with an iron grille.
2. A common latrine with separate stall for each floor, also locked.
3. The provision for a minimum frontage to each house,
4. „ „ „ a maximum depth to each house.

1 & 2 should be under one roof and kept away from the house and approached by an open sided covered way, and be one storey in height only. All kitchens and latrines in other parts of the house should be abolished. 3 &4 should make for the reversal of the present plan; that is—the depth of the house should be sufficient for two rooms and a central passage only, or about 25 feet; while the frontage should be increased to admit of four or more rooms of a minimum width of 7 ft. each or say 30 ft. per house exclusive of walls. This

plan will give four rooms in front and three rooms and a staircase at back, the passage being only necessary between two pairs of rooms. The size of the rooms can be regulated according to requirements; each room can have adequate window space; the staircase can be well lighted and made a valuable aid to cross ventilation. Where the ground floor is used as a shop a portion must be sacrificed for the staircase. This only means a narrow strip, the width of one flight, taken from the frontage, and a little more at the back to give access to the yard. This plan can be repeated floor by floor to any height, and added to on either side to practically any extent; for the main streets follow the contour of the hill side, and each successive row being higher than its neighbour gets good rough ventilation. On the lower flat ground through ventilation can be got by making the streets and yard spaces wider.

In a climate like this (Hongkong) verandahs should be built over all side-walks and carried up from the road level: the advantages gained are many. They enable the public to walk the streets in any weather protected from sun or rain. They enable windows to be kept open day and night, and with streets of proper width do not interfere with the main air current; but they should not be obstructed by any projections beyond the frontage, such as shop signs or bamboos displaying clothing or goods for sale; neither should any of these things be allowed upon the ground floor or side walk portion. Any shop signs or announcements can be affixed to the faces or sides of the pillars, and tradesmen should not be allowed to carry on business on any part of the space devoted to the public. These may seem to be matters concerning the Police only, but I make no apology for alluding to them here.

For details as to window area, ventilation of latrines, floor space to be provided for various purposes and such like, reference should be made to the various regulations in force in different localities, remembering always that these regulations provide the minimun permissible requirements only.

One of the most important points in the planning of a dwelling of any kind is the position of the W.C. This, whether it be a dry closet or a water closet, should be so placed that it is without the four walls of the building altogether, and is approached by a cross ventilated corridor; where more than one is required, they must be kept over one another for convenience of drainage and water supply. Due regard should be had to privacy, and separate closets for persons of either sex provided. Every closet must have a window opening into the external air, and as large as possible; skylights are not advisable; ample light is a necessity. The fittings should be simple but good, for good things are usually well kept and are consequently clean.

Schools should have rooms of a height of 12 to 14 ft. and floor space of 10 square ft. per pupil. Windows should be carried up to the ceiling and ample light provided. Top light is best where possible. Direct sunlight during school hours is not advantageous. In school dormitories each bed should have a minimum of 3 ft. 9 in. of wall space, 36 ft. of floor area, and 360 cubic ft. of space. Masters' rooms with an observation window are required at one end of each dormitory. Cubicles are not advisable on sanitary grounds. Dormitories should not be used for study during the day.

Lavatory and bathing accommodation must be ample; if possible one wash basin to each boy is not extravagant.

Closet accommodation should be 15 per cent. for girls, 10 per cent. for boys. with additional 5 per cent. of urinals. Cloakrooms with two or more separate pegs for each scholar are needed, and should be kept separate from the schoolrooms. Classrooms must be of moderate dimensions to enable the master to make himself audible to the whole class without straining the voice. Married masters should be provided with quarters quite separate from the scholars.

Hospitals are hardly within the scope of this lecture, but a few leading points may be briefly noticed. The administration block should be kept separate from the wards and connected with them by cross ventilated corridors. It should contain the secretaries' offices, board-room, steward's offices, stores, matron's and doctors' residences, and servants' dormitories and the kitchens. Night and day nurses should have separate accommodation. Separate dining-rooms for male and female servants. Wards should be separated by cross ventilated corridors. Baths for patients should be easy of access from the wards without passing through draughty corridors. W.C. and lavatories placed in separate wings with cross ventilation between them and wards. A nurses' room and ward kitchen are usually arranged to each ward. The nurses' room should not be used for sleeping purposes.

The operating room should be easily accessible from all wards, yet completely severed from aerial contract with them or the kitchens, laundry or mortuary. Out-patient department should be one floor high and detached from the main buildings, the mortuary also. Isolation wards are necessary in children's hospitals, and lying-in hospitals, the latter should be constructed with small rooms, not large wards.

Infectious diseases hospitals require much more air and floor space, and should have wards for each class of disease, and administrative and nursing blocks, and isolated accommodation for the small pox staff. Disinfecting apparatus has to be provided for. Blocks of wards should be at least 40 ft. apart and each contain closets, baths and sinks, linen, store, and fuel rooms, as well as nurses' rooms. A building is required for patients leaving the hospital containing three rooms: one where the patient undresses and leaves infected clothing, the second a bath room, and the third for putting on clean clothing before leaving. This room communicates directly with the open air outside the grounds of the hospital, and no person once outside should again enter the premises.

In conclusion let me again draw attention to the principal points to be remembered in arranging for the ventilation of buildings.

Theatres and the Like.—Warm the auditorium before admitting the audience. Arrange that the air current shall set from the stage or platform towards the audience. Treat each tier or gallery as a separate floor. Maintain a temperature of about 70° F. equally throughout the auditorium. In hot weather the sliding roof is an invaluable means of ventilation.

Dwelling Houses.—Warm the hall and staircase. Provide separate inlets for each room proportioned to the probable number of occupants.

Churches.—Warm the building before admitting the congregation. Check the cooling and condensation produced by the large windows. Provide ample inlets. Arrange that the air current shall set towards the congregation and from the choir and clergy. Screen all doors.

Schools.—Warm the classrooms before admitting the children. Provide ample inlets, treating each room separately. Cross ventilate cloakrooms, lavatories, etc., and isolate them from the classroom.

Hospitals.—Cross ventilate between each ward, and between wards and lavatories, kitchens, etc. Introduce the fresh air at the bed head and provide an inlet to each bed below the level of the pillow.

Factories.—Introduce the fresh air as near as possible to the individual workman. Provide for the rapid extraction of heat or fumes from the processes employed. Remove dust filings, sawdust, etc., from the bench by extracting blowers as soon as they are produced.

In the time at our disposal it has only been possible to deal with the great questions of ventilation and housing in a general way. Many points arise upon which whole books might be written; it has been my endeavour to indicate lines of study rather than to attempt to teach. Success can only be obtained by working out each problem as it comes before us, combining the enthusiasm of theory with the common sense that is gained by experience.

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SANITARY BUILDING CONSTRUCTION

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A HEALTHY dwelling should combine the following advantages:—

1. A proper site.
2. A supply of pure water.
3. A proper system of ventilation.
4. A system of removal of refuse and sewage, both immediate and perfect, which renders contamination of air and water supply impossible.
5. A condition of construction which insures perfect dryness of foundations, walls and roof, and above all cleanliness.

Nos. 1, 2, 3 & 4 are dealt with in other lectures. No. 5 can be conveniently discussed by following the construction of a house step by step, from the purchase of the ground onwards.

Assume that the house is to be erected upon a site where roads and sewers are made, and water laid on. The first thing to be done is to ascertain the nature of the soil, to decide upon the foundations, and arrange for the exclusion of ground air and damp. The ground being found to be solid and of the same nature all over the building, the trenches are got out, and a layer of concrete put in to form a base for the walls. The only permissible ingredients for concrete are clean stone, gravel, and sand, with lime or cement. Garden mould, road sweepings, and any earth likely to contain organic matter must on no account be used. The red earth used here (Hongkong) makes excellent mortar and concrete when combined with lime, but requires most careful mixing or it is no use. Mixing is the great difficulty met with all over the world and especially here; probably concrete mixing is the hardest work that the labourer is called upon to perform, and it is therefore the more often shirked.

For the exclusion of ground air on sites likely to be contaminated with organic matter, more especially on made ground, a layer of concrete not less than six inches thick is usually provided. Unless this concrete is good, and carefully made, it is very little protection; a thin layer of asphalte in addition will be necessary to ensure perfect safety from emanations of sewer gas, leaky gas pipes, and organic impurities which the warmth of the house will suck in. Those parts of the ground floor which are practically on the ground, such as entrance halls and passages, should be paved with tiles set in cement, mosaic or terazzo paving, or some impervious material. Wood blocks set in asphalte on a layer of good concrete may be used where slop water is not thrown; but they should be wax polished to prevent water from soaking in, and the joints made with pitch or asphalte.

Drains should never be laid under a house unless made of iron pipes, and so placed that every part of them can be seen, and leaks at once detected. Buried pipes whether iron or stoneware, even if surrounded with concrete, are not absolutely safe, though in some instances all chances of settlement and fracture may be, humanly speaking, avoided. Where the ground floor is boarded, provision is made for air circulation between it and the concrete covering the ground surface; the minimum distance provided by law, between the underside of the joists and the surface of the concrete, is in many cases as little as nine inches. This is not enough. There should be room for a man to crawl in through a proper opening for cleansing the space; the minimum provision of air bricks is often insufficient for the circulation of air. The air must move; if stagnant it is a source of danger. The openings must be sufficiently large to ensure thorough circulation and they must be made through the internal walls as well as the external. We often find openings left in the outside walls and all circulation cut off by the small sleeper walls, put in to carry the joists. There is nothing better than an open basement with sufficient head room for a person to walk upright, well lighted with doors and windows closed to the entry of cats and vermin by fine wire netting. The usual objection to this arrangement is cold, but this can be avoided by grooving and tonguing the floor boards, pugging and so forth. Few floors are laid nowadays actually on the ground; experience has taught the most parsimonious of landlords that it is cheaper to avoid dry rot by providing air space.

While on the subject of floors it will be well to consider some of the materials used in making them. Cement rendering should never be less than one inch thick; two inches is better if it be applied after the concrete is put in. The best floor is finished at one operation, by beating up the surface of the concrete as laid, with a shovel and finishing with a float; in this way the whole thickness of the concrete becomes the floor and will not peel or work up. It is difficult to get this carried out in practice. A thin skin of neat cement put on a floor that has set is practically useless and sure to peel off. Tiles, mosaic and terazzo should be well bedded, at least two inches being allowed between the underside and the surface of the concrete. In terazzo work take care to get the whole surface marble, not cement, or it will not polish and keep its colour. The marble should be at least half inch deep, smaller pieces work out with wear. All floors of this kind should be rounded up to the skirting or wall to one inch radius, this keeps water from leaking over the edge and facilitates cleaning, it also leaves no corner for the harbouring of germs, dust, etc. Internal vertical angles of walls should be rounded in the same way.

For wood floors, hard woods such as oak, teak and elm are preferable, and they should always be grooved and tongued and wax polished. Maple makes an excellent floor if laid in narrow widths, but is not easy to get: soft woods are seldom used in hospital construction on account of their facilities for harbouring germs. Skirtings should be grooved to the floor, and in all cases the plaster must be carried down behind them to the floor level. In factories or places where much hard wear comes on the floors, a lining or second floor of elm is sometimes laid over the floor proper, the joints running the same way as the under floor, but breaking joint. This saves grooving and is easily renewed when worn. The treads of stairs can be treated in the same way. In France even in small houses, the upper floors are laid with concrete and tiles; the objection that such floors are cold is not so serious as it appears, while the benefit gained in cleanliness, sound and fire resistance is invaluable. When laying a concrete floor on wood joists, do not nail the rough boarding to the fillets, cut them with room to expand when wetted. Concrete always parts with a quantity of water while setting; this swells the wood and causes cracks. The rough boarding is better if soaked for some hours previous to putting in the concrete. Coke breeze concrete is useful where lightness is necessary, but it is not fire resisting, boards can be easily nailed to it, and it forms a good key for plaster. Good solid floors can be made on metal lathing in this way.

For checking the passage of sound pugging is resorted to; a layer of some non-conducting material is packed between the floor boards and rough boarding fixed below them. Sawdust, chopped straw and rubbish are not good materials: lime mortar, slag wool, and silicate cotton are good. When sawdust is used for pugging partitions it settles down gradually, leaving an empty space in the upper part; slag wool does not do this and moreover it does not harbour vermin. The ground floor should always be kept at least six inches above the level of the ground outside, and a damp course put in above the ground and below the floor. Common bricks absorb as much as one pint or a pound of water, which readily diffuses itself by capillary attraction, and has been observed to ascend as much as thirty-two feet from the foundations. This wet has to be evaporated and lowers the temperature inside the house. Damp walls cause rheumatism, lower strength, and expose the system to other passing causes of disease. There are several forms of damp proof course. Glazed pottery slabs perforated, may be built in, but damp rises through the joints. A layer of tough asphalte three-eights of an inch thick is best in cold climates. Slates set in cement are liable to crack. Sheet lead is efficacious but most expensive. A layer of cement and sand ($\frac{1}{2}$ sand to 1 cement) is best and should be three-quarters of an inch thick. Wet may be kept out by rendering in cement, slate or tile hanging, but the latter should be nailed to breeze fixing blocks, not wood battens. Hollow walls exclude damp, and the layer of air contained, being a non-conductor of heat, keeps the building warm. They are better built with the thicker portion inside, to carry the weight of floors and roof, and expose the thinner portion to the exterior moisture. Tiles or bonds are required, the best form of these being of strong twisted wire. They do not hold the falling water, or mortar used in construction, and if galvanized are practically indestructible.

Mortar should be thoroughly mixed and completely fill the spaces between the bricks. To ensure this, every course must be well flushed up *before* spreading the bed for the next course. Grouting should not be allowed. It is most difficult here (Hongkong) to get brickwork even decently done; the bricklayers work on very flimsy scaffolds which will bear no weight, consequently the unused bricks are piled along the top of the walls, preventing lines from being stretched, and level courses laid. The bricks vary very much in size, so that perpendiculars are difficult to keep, and bond is looked upon as a fad of the "Foreign devil." Old English bond is the best in the thick walls that obtain here, but the Chinese do not understand the use of "closers." If the authorities insisted upon good bond, there would be no necessity for the abnormal regulations as to thickness of walls now obtaining. These regulations allow for no reduction in thickness for walls that are built in cement mortar, though it is admitted that such walls will carry twice the load per superficial foot that lime mortar walls can take. Absolutely impervious walls are not desirable; the surface condensation on the interior is much greater, for instance, on a solid granite wall than on one of brick, and spoils decorations such as paper-hangings, besides damaging pictures and furniture. Another abominable practice in vogue here is the leaving of enormous putlog holes, more often than not in piers, and the reckless cutting away of piers for fixing pipes and so forth. The Chinese scaffolder loves to stick a 6 in. pole diagonally through a pier, so that he may balance a miserable plank on each side of the wall for his bricklayers to work upon. These holes are a constant source of anxiety to the architect. Large windows and therefore small piers are necessary. He cannot afford to lose the square foot of sectional area that these putlogs rob the pier of; and unless he personally sees each one pinned up, the contractor puts half a brick in on each face and leaves the middle empty. For my own part I endeavour to prevent the use of putlogs in all piers, and after much trouble have got them to scaffold through the windows, a method which makes no difference in the cost of scaffolding, when once the "olo custom" fallacy is disposed of. All bricks should be thoroughly wetted immediately before laying, and mortar should be mixed and mixed again after the coolie who presides at the banker thinks it is fit for use.

A good rough method of testing lime for the commonest adulterant (sand) is to shake some up in a wide mouthed bottle with about an equal quantity of water. After being well stirred it should be allowed to settle, when the sand will sink to the bottom and the amount in the sample can be easily estimated. A small quantity of cinder will be found in the best lime procured here, but lime containing sand in any proportion over 10 per cent. should be rejected. This experiment should not be carried out over the best tablecloth, as the expansion of the lime frequently breaks the bottle. Large pieces of unburnt limestone are also used to adulterate lime, though it is difficult to see where the profit to the burner comes in. In mortar composed of local red earth (decomposed granite) and lime, the proportions found best are one of lime to three of red earth, more lime does not improve the mortar.

Every fireplace should have its own separate flue; circular pipes make the best flues. They should be bent sufficiently to prevent daylight being seen when looking up the flue; this prevents rain or sleet from falling directly on to the fire and checks down draughts of cold air. The opening above the fireplace should be gathered over so as to be contracted to the size of the flue, this prevents cold air from entering the flue before it has been warmed by coming in contact with the fire. Chimney stacks should have external walls of not less than nine inches thick to prevent cold air penetrating from outside, causing the chimney to smoke. Fireplaces should be kept within the house as much as possible, that is not against outside walls. No wood of any kind should approach nearer than nine inches to the inside of any flue. Flues should be "pargetted" or rendered with good mortar and cowdung inside, and no projections or mortar droppings allowed to remain in them. A sack filled with shavings and weighted is dragged up and down newly built flues for the propose of removing any obstructions; this operation is called "coreing."

Partitions are used to divide rooms from one anther instead of walls, to save weight, space, and expense. "Quartered" partitions consist of framing, upon which laths are nailed and plastered. They are sometimes called "French walls" by the Chinese. The objections to this form of partition are that they form a hollow space in which air stagnates, and rats and other vermin can be concealed, and that they are not sound proof. When used, the plaster should be carried down to the floor behind the skirting, and some form of pugging resorted to, such as slag wool. Brick nogging is seldom satisfactory, as it leads to rotting of the timbers, and does not compare favourably with brickwork either as to weight or expense. A half brick wall in cement mortar is one of the best forms, but is not self supporting and requires a girder to carry it. Several patents have been taken out for thin partitions; most of them use plaster slabs in different forms, stiffened with iron rods, expanded metal, or neat cement run into tubular joints. Many of these are good, but all fail in that they do not permit of the convenient fitting of windows, doors, mouldings and so forth, and woe betide the unfortunate man who tries to cut a hole in one of them for any purpose.

Ceilings whether of wood or plaster are liable to harbour vermin, but it is possible to avoid this to a great extent by exercising care in their construction. The ventilator board used in the upper member of the cornice allows light and air and sound to penetrate, and no doubt tends largely to prevent the ravages of white ants; but the large holes permit cockroaches and mosquitoes to retire to the seclusion of the ceiling during the day, from whence they issue at night in search of prey. I cover the back of the ventilator board before fixing with fine bronze wire gauze. This keeps the insects in the room, where they can be pursued and destroyed; it allows air and light to penetrate the space under the floor, and being fixed on the back or upper side of the board does not hide the pattern, or become stopped up with paint. Bronze will withstand climatic influences and the cost is not great. The same gauze may be used with advantage in door and window openings, but not unless the ventilator boards are also covered with it. In plaster ceilings the laths are best rent, not sawn, and the fixer should be able to put his finger between any two laths after fixing: this space ensures a proper amount of plaster being squeezed through the laths to form a key. Lathing on timber is no use unless it be kept half an inch away by fillets, for the same reason. Roofs should be wind and watertight; the former requirement is often neglected, and driving snow, dust, and other impurities find their way in. Boarding and felt are necessary under slates or tiles, and the battens are best fixed over the felt; this allows a small air space between slates and felt, and forms a good non-conductor. Corrugated iron should always be boarded on underside for the same reason. Do not put felt under lead or zinc, it soon perishes and allows the metal to be dented by persons walking over it.

The storage cistern is commonly placed in the roof space: this is a bad practice, as the interior of most roofs is dirty, and the position inaccessible. Boarded gangways should be laid on the ceiling joists for convenience in getting at the inside of the roof, and all trap doors made large and well fitting, and hung on hinges. Sufficient glass tiles must be inserted to adequately light the roof space; nothing helps to prevent the accumulation of dirt and vermin more than daylight and fresh air. Ventilation should be provided for by properly protected openings which will exclude birds, cats and so forth. Flat roofs are useful things in moderation, but are difficult to keep watertight; a concrete flat will crack in this climate (Hongkong) unless provision is made for expansion and contraction. It will however keep tight if always flooded with water a few inches deep; unfortunately this is seldom practicable. A properly laid lead flat is satisfactory, but the lead is liable to be stolen.

Wall coverings should be impervious and as smooth as possible; trowelled Keen's cement or Sirapite is best, as these can be brought to a polished surface. All internal angles should be rounded. Projecting mouldings can be formed so that their upper surfaces are easily kept free from dust and still be made beautiful. Deep undercut enrichments are to be avoided. They harbour dirt and soon become clogged with whitewash or paint. Paper hangings should be cleaned off right down to the plaster whenever renewed, and the corners well cut out; this of course necessitates good plastering, or the plaster may come down with the old paper. The colour of wall papers and other decorations is important. Monotony is depressing, and excessive variety of effect is distracting. Quiet but not sombre colours are advisable, and patterns should be designed with massed effects. Faithful representations of natural objects are often ludicrous, as when dragons or other animals are bent round corners, or appear holding heavy swags of fruit and vegetables in their teeth. Patterns that can be "counted" should never be used in bedrooms, and imitations of tiles or other similar materials are to be avoided. Many excellent designs can be had at prices to suit all pockets, and a good wall paper will go a long way towards furnishing a room. For the preservation of plaster from damage by chairs, the so-called chair rail is seldom effective. A better plan is to put a fillet round the floor to catch the chair legs at the bottom. These details, though small in themselves, do not make great additions to the cost of a building; but they add largely to the comfort of the inmates, and discomfort is only another way of writing the word "disease."

Doors affect the sanitary condition of a house to a considerable extent; they should fit the frames and have serviceable fastenings. Handles of lock furniture should be well secured to the door as well as the spindle. Small locks place the handle too near the edges of the door and cause injury to the knuckles of persons using them. Hinges should have loose pins where exposed to the weather. The size of the openings should be considered with regard to the furniture. Swing doors must be glazed, to allow persons who are approaching from opposite sides to see each other. Hospital doors are better made solid and flush both sides and all unnecessary mouldings omitted. The upper sides of rails in panels should be rounded or splayed to prevent the collection of dust. Particular care should be taken in cleaning off the tops and bottoms perfectly smooth and in seeing that they get painted.

Cupboards when not carried up to the ceiling should have their tops raked back so that the whole surface is in sight, and all shelves made to remove for cleaning. Linen cupboards require ventilating from the outer air, otherwise the heat in them will draw in dust at all possible crevices. Pantry windows and doors should have wire gauze screens to exclude flies. Slate or marble shelves are better than wood for keeping food.

Windows should never be provided for the sake merely of external effect. All kinds of glazing which diminish the light, and are troublesome to keep clean, should be avoided. A large portion of each window should be made to open for ventilation and cleaning. Windows should be carried up as near the ceiling as possible, large spaces between the window heads and the ceiling being productive of foul rooms. Skylights are objectionable and should never be used where windows are possible. Unless fixed they are liable to leak, and are at all times difficult to keep clean. Sashes should fit the frames and exclude water and draughts; provision should be made for carrying off condensation. In hospitals it is better to avoid subdividing frames by transoms which collect dust, and pivot hung sashes closing one upon the other give the greatest amount of air space while affording small surface for dust to lodge upon. The rebated edges of the sashes are easily got at for cleaning.

Linings and skirtings should be fixed to tarred grounds and the plaster brought up to the face or the grounds before lining. The wrot ground should not be used as a screed for plastering, or it cannot be painted properly. Window and door frames are best fixed with short angle pieces of hoop iron tarred and screwed to the frames and built in as the brickwork goes up. Wood blocks when used for this purpose are liable to shrink and they break the bond and weaken the wall. Fitments such as are frequently recommended by furnishing contractors, are not permissible in bedrooms: cupboards, wardrobes, drawers, and so on are best moveable, and should be frequently moved. Box or folding beds are most objectionable, as the bedding does not get properly aired. All bedding should be aired for at least half an hour with all windows open after use; this does not mean merely turning back the upper sheets and covers, but stripping all the bedding from the bed and putting it about the room, while the mattress is turned up on edge and left so. This practice is not easy where the bedstead is made part of some fixed article of furniture such as a book case.

Fixed lavatories with hot and cold water laid on are preferable to washstands with loose basins, but better still, have all washing apparatus kept out of the bedroom and arranged in a dressing room adjoining. Lavatories do not properly come into this lecture, but I should like to enter a protest against all traps inside the building, whether for lavatories, baths, or sinks. If these waste pipes are large and laid to good falls, and kept open at the ends, with cleaning screws for access to every part of the pipe, there is no need for traps, or any hoarding up of filthy water, and it rests with he housekeeper to see that they are periodically cleaned. Another point to be insisted upon is the size of taps and wastes. These should be large: a 3 in. waste plug is not too large for a bath, 1½ to 2 in. clear way for a lavatory, and 2 in. for a sink. This provides that the dirty water shall get away quickly and leave no deposit of soap on the surface of the basin. If nothing less than ¾ in. taps be used for lavatories, and 1 in. for baths, they get filled quickly and flushed properly and no more water is used. If the taps be small they get left open and forgotten, causing waste; and they are more likely to get out of order, because there is not room for strong construction and good fitting. All supply pipes should have stop cocks, to enable taps to be taken to pieces and cleaned without calling in a plumber. My idea of a perfect house is one in which all ordinary fittings are so arranged that any person of average intelligence may rectify small mishaps, such as dripping taps, blocked pipes, and so forth, without "having a man in." Unfortunately if a workman be called in he rarely confines his attentions to the job he has been asked to do, and the result is that something else is found to be wrong immediately he has left. There is apparently an unwritten law that scaffolders shall break windows, plumbers break slates, and destroy mahogany seats and bath enamel by wearing hob nailed boots, If the "skilled" man does not, then his "mate" does. Any "engineer" will leave black grease marks on paintwork, and bricklayers!!——but why continue?

Gas pipes should be iron and *painted* at least two coats before fixing; even the best brand of pipe will develop a seam and leak, that is, in the pipe itself; the joints can be more easily seen to. Compo pipe is dangerous as a cause of fire, though when a house is well alight it makes little difference whether the pipes are iron or not if gas be in them. Leaky gas pipes are a cause of disease apart from the danger of explosion. Epidemics of boils have been traced to leaky gas pipes. If acetylene gas be used the pipes require to be much smaller and of copper, much greater care must be taken to prevent leakage, as this gas will penetrate the pores of the metal itself. Its great safeguard lies in its abominable odour, which no one can endure for long, so that leaks are searched for and stopped very quickly.

Electric light and bell wires should be well insulated and enclosed in metal pipes; the common cotton covered wire used for bell work in most suburban houses is of little use. The insulation is imperfect to begin with, and the moisture in the plaster soon completes its destruction. When a house is fitted with bells for half a crown a point, including everything, what can be expected but failure; nevertheless this is the sum paid for hundreds of houses near London that let at between £35 and £60 a year. The lighting companies generally insist upon the use of a certain standard of wire, but even then the fixing is often defective and no metal tubes are used. A picture nail carelessly or ignorantly driven may cause considerable damage and inconvenience. Switches are often of the most rubbishy description, and in damp weather very unpleasant if not dangerous shocks can be got when using then. They are frequently fixed so badly that they become loose; this suggests a reference to that small but important detail—the fixing block.

Now there is only one way to plug a wall for fixing bell blocks, gas blocks, switches, or the hundred and one things that have to go up after a house is finished, and it is this. A hole must be cut in the brickwork of "Lewis" shape, that is, larger at the inside than it is outside, and it must not be more than 4 in. × 3 in. in its largest part, or more than 4½ in. deep. It is better to place it so that its centre comes on a joint if possible; taking out a half brick will not do. The block must be cut "Lewis" shape and have its outer face with the grain, *i.e.* no end grain must show or it will not hold screws. Its large end must be equal to the small outer end of the hole, and it must be fixed by filling the hole with cement mortar and jamming it in. A block fixed in this way may shrink, but it will never draw; if fixed any other way it is sure to fail sooner or later. A long moulding such as a picture rail may be fixed to good brickwork by driving 5 in. cut nails about eighteen inches apart into joints, but blocks are better; and it is well to remember that pictures worth hundreds of pounds may easily be ruined by the collapse of a picture rail costing less than one.

Pipe casings should be fixed with screws, never nailed, and the plastering should be carried in behind them; they form most convenient harbours for vermin if not carefully fitted. All water and gas pipes should be laid to fall towards outlets so that they can be completely emptied for cleaning or in case of frost. When fixing water waste preventers in the very high rooms that are found here, do not put them more than six feet above the pan connection, or they will not give a proper flush. This point is often neglected and the cistern wrongly blamed. Baths should not be cased, and are better kept well away from the walls for convenience of cleaning; the same applies to lavatories. Good fittings are easily obtained at reasonable cost, which require no casing, and all parts are visible and sightly.

The warming of a building is of great importance with regard to health. Steam pipes dry the air too much; radiators, whether heated by high or low pressure hot water, do the same in a lesser degree, and provision must be made for evaporating water near them to keep the air in a proper state of humidity. Coal stoves when placed out in the room also require water pans for this purpose. There is no healthier form of heating than by the direct radiation from an open fire; a bright clear fire is sociable, cheerful, and in a properly constructed open grate a good thing to have in any room. The noise of the crackling coal or wood, the latter for choice, is an eminently comforting one, and far preferable to the sullen roar of an asbestos gas fire, or the silent radiator, or hot water pipe. It consumes the foul air that it draws out of the room, and if properly tended does not create a large amount of dust. A coal fire should not be buried in a hole in the hearth; recent patent stoves are made on this principle, which I think is a bad one. Certainly the appearance of a "Well" fire is melancholy in the extreme however scientific it may be. After all, economy is a personal matter; bad firing will waste fuel in any form of grate. What can be more comfortable and sociable than the old fashioned settle, now alas! found only in remote country inns, where the village fathers gather in the evening and sit round the hearth, protected from draughts and getting the full benefit of the fire? The so called "cosy" corner is rarely cosy, and is more often than not away from the fire. Our forefathers understood solid comfort better than we do, and although we have improved in taste, I doubt whether we get as much for our money as they did in the matters of food and lodging.

Hot water services require pipes of ample size; nothing less than $\frac{3}{4}$ in. branches, $1\frac{1}{2}$ in. flow, and $1\frac{1}{4}$ in. return pipes should be used. The head of water, *i.e.* the distance between the bottom of the cold water cistern and the highest point of the hot water service, should be not less than 5 ft. Draw-offs are better on circulation pipes; long branches forming dead ends must be avoided. All main flow pipes must have return pipes, and a storage hot water tank up stairs will be required where there are baths, in addition to the cylinder near the boiler. For small installations, such as say one bath and a few draw-offs, the boot boiler behind the kitchen range gives sufficient power, but in hotels or institutions it is necessary to provide a separate furnace and boiler to get the requisite supply. If these rules are observed an adequate supply will be obtained which runs hot immediately on opening the taps; but if not, cold water will have to be drawn off in considerable quantity before the hot comes. This wastes water and also wastes fuel, for the kitchen fire is kept in much longer than necessary with its large grate area, when a small furnace burning half the coal would do the work.

In conclusion I should like to say one word on the subject of drain testing from an architect's point of view. Many Inspectors refuse to see and test drains till the whole system for any one job is complete, and then insist upon filling the whole drain with water up to the level of the highest gulley. This results in putting upon the drain a test which it will never be called upon to endure in practice, and which requires "boiler work" to enable it to stand. Drains should be tested in lengths and under no more than 2 ft. head of water; and if this is not practicable, the water must be run into the pipes very slowly, so as to allow the air in the drain to escape. One inspector I had the misfortune to have to deal with, insisted upon filling the upper section of a long drain with 20 ft.

fall in it, first, and then let the whole of the water in the higher half go suddenly to fill the lower portion of the drain, with the result that the air got locked in the lower end, and the water "surged" so violently that it blew the plug out. If that plug had not gone, there is no doubt that one of the pipes (which were DOULTON's "tested") would have burst. I succeeded in persuading him to adopt milder methods of testing in this instance, but only after giving him formal notice that he would be held responsible for the damage caused.

If a drain becomes blocked at its lower end and filled with sewage, it is filled gradually, and much of the matter contained in the pipe is solid, and does not exert so much pressure as water, moreover the pressure is gradually applied and is not so severe as that obtained by filling the whole system up to its highest point. The best and most reliable test is that applied by air pump and water gauge. If the drains be plugged, the traps filled with water, and an air pump to which is attached a water column pressure gauge connected, a pressure sufficient to lift the gauge slightly is all that is necessary, and any leakage is at once easily seen, by the falling of the water column. Apparatus for this purpose can be had for a few pounds and should be in the hands of all drainage authorities. It can be used for all purposes, for both drainage and plumbers work. If the work be found defective, leaks can then be located by the smoke or water test, as most convenient. So long as earthenware pipes are recognised as adequate for underground drains, they must only be subjected to tests which they are capable of bearing. If drains are expected to be as strong as steam boilers, then they must be constructed of different materials.

SEWAGE DISPOSAL AND THE TREATMENT OF SEWAGE

By ARTHUR H. OUGH, A.R.I.B.A.

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IN dealing with this subject I have confined myself mainly to the question of sewage disposal by chemical processes, and by the agency of bacteria. Treatment on land by broad irrigation, intermittent downward filtration, and other systems where raw or crude sewage is dealt with, without previous efforts to clarify it or precipitate the solids and organic matters in suspension, is merely an imperfect form of biological purification, and will in time be almost universally superseded by bacterial treatment in tanks, where the process is under control, and can be carried out with greater economy in less space.

Those authorities whose duty it is to dispose of sewage and other refuse are gradually abandoning the idea of making a profit out of the process, and are content to get rid of offensive matters in the most economical manner consistent with safety. In a few cases the sale of clinker from destructors goes some way towards meeting the expenditure, but a market has yet to be found for sewage cake in large quantities.

Raw sewage is the term applied to water borne solid and liquid excreta of men and animals, waste water from sinks, lavatories, stables, slaughter-houses, trade and manufacturing refuse of widely differing descriptions, and the surface water from roofs, streets, and yards of houses with its accompanying mineral detritus.

The sewage of towns varies largely in its composition: the fact of water closets or earth closets for the removal of excreta being in use makes little difference to its character. Some towns, by reason of the carrying on of certain trades such as wool sorting, dyeing, tanning and chemical works, produce sewage more highly charged with difficult matter for treatment than others where the residential element prevails. For example:—The sewage of Bradford offers exceptional difficulty by reason of the amount of wool-combers' refuse present, while that of the Metropolis, though containing practically every known species of refuse, is more easily dealt with on account of the diluted state in which chemical discharges arrive at the outfall.

Dibdin gives the constituents of London sewage as: suspended solids=27 gr. per gallon, of which 15 gr. is organic matter, and the remainder liquids, of which 20 gr. is organic. The sewage of Bradford experimented on at Roubaix contained: total solids 127 gr. per gallon, chlorine 10 gr. per gallon. The average composition of sewage from towns where the excreta are water borne, and those where the bucket or "midden" system obtains, were given by the Rivers Pollution Commissioners (1868) as follows:—

	In parts per 100,000	
	Water Closet Towns.	Midden Towns.
Total solids in solution	72·200	82·400
Organic carbon	4·696	4·181
Organic nitrogen	2·205	1·975
Ammonia	6·703	5·435
Total combined nitrogen	7·728	6·461
Chlorine	10·660	11·540
Suspended matters		
Mineral	24·180	17·810
Organic	20·510	21·300
	44.690	39·110

In inspecting the methods adopted for purifying or destroying the sewage collected from "midden" towns, it will be sufficient to consider only those where attempts are made to render it inoccuous, disregarding the large number of places where it is simply collected and put on the land without treatment, or carried out to sea. It will be useful in passing, however, to mention one instance where the bucket system, pure and simple, is universal.

In this colony (Hongkong) the climate is tropical; water closets are prohibited, with a few exceptions in large blocks of offices and public buildings; the excreta are deposited in earthenware pans, and regularly collected in the early morning in covered buckets. These are in their turn emptied into specially constructed boats, which convey the sewage across the harbour, where it is disposed of to contractors, and eventually used as manure.

There are objections to this plan, such as occasional accidents to the carrying coolies, and the fact that the liquids are frequently emptied into the surface water channels. There is the inevitable odour, caused by the fresh excreta, to be perceived where the pans are indoors. No attempt, however, is made to avoid this by the use of water, earth, or disinfectants, partly in consideration of the cost of removal, and partly because the climate is such as to enable windows to be kept open at all times. The increasing pollution of the harbour by sewage is noticeable in the state of the foreshores, and the time is approaching when the question of sewage disposal will have to be seriously considered in Hongkong.

The methods of minimising air pollution during removal, and delaying decomposition in the excreta, where the dry or "midden" system is in use, are numerous. Of these the most sucessful is the addition of dry earth.

MOULE's closets provide for the discharge of a small quantity of dry earth on the sewage. The contents of the receptacles are stored for a time, to enable the organic matter to be broken down, and the whole dug in, or dried and re-used. The objections to this method are the difficulty of obtaining suitable dry earth, especially in towns, and of excluding house slops from the receptacles. Similar closets are used with charcoal or ashes in place of dry earth, the mixture being afterwards burned or dug in as manure. The question of expense is the great objection in this case.

In the "GOUX" system the receptacle is lined with peat, or a compost of tan, sawdust, and soot, moulded to the sides of the pail. Practically these act as dessicators without deodorising, and the mixture is difficult of disposal.

In FRYER's patent the excreta are collected and dried in a closed apparatus, the ammonia being fixed by the sulphuric acid fumes obtained from carbonising garbage, street sweepings, and town refuse, in a destructor.

The continental system of collecting the filth in a large receptacle in the basement of the house, and afterwards drying in open tanks by exposure to the air, needs no comment.

The LIERNUR and BERLIER systems extract sewage by exhaustion of air in the drains, collect and dry it by heat, and form poudrette. They fail from clogging of the pipes by adhering fæces, and the consequent use of water which interferes with the proper working of the system.

The disposal of water borne sewage commences at the outfall.

It has been proved by past experience that the raw sewage of inland towns must not be permitted to flow into rivers under any circumstances, and with the exception of cases in which certain conditions exist, it must not be discharged into the sea, and never into a land-locked harbour. It becomes necessary, therefore, to so purify the sewage that it will not contaminate the water to the destruction of fish, or silt up the bed of the stream by depositing suspended matter. There are numerous processes for effecting this purification, all of which have been tried with varying success. These may be divided into two classes:

1. Chemical processes.
2. Biological or bacterial processes.

In the first the objects to be attained are:

1. The precipitation of the solids and organic matter, forming sludge.
2. The destruction or disposal of the sludge.
3. The purification of the remaining liquid or effluent.

In the second class, precipitation is employed for the removal of mineral matter before treatment. No sludge is formed, sterilisation is not attempted, and bacterial growth is encouraged.

In chemical purification most systems are similar in general principles; large objects such as brushes, wood, and hardware being removed from the raw sewage by means of coarse screens. It is then collected in tanks and allowed to remain quiescent, so that the solids subside; chemical precipitants are introduced which entangle and take down with them the suspended matters and some of the dissolved organic impurities; the liquid is decanted from the top and allowed to run into the nearest watercourse, or passed on to land, leaving the sludge which usually contains about 95% of moisture. The sludge is removed and dealt with in various ways. In London it is pumped into specially constructed steamers and taken out to sea, where it is discharged. In other places the moisture is expressed by powerful machinery, and cake formed which is of small value as manure. Great difficulty is experienced in getting rid of the cake. Farmers frequently refuse to cart it away, and it has to be burnt, or dug into land provided for the purpose,

The more important chemical precipitation processes are as follows:—

The Lime Process.—The purest obtainable lime is dissolved in water (or the clarified effluent), and added to and thoroughly mixed with the raw sewage. The quantity of lime required is about 16 gr. per gallon, varying with different kinds of sewage, but reduced to the smallest effective amount in order to avoid putrefaction of the effluent; an alkaline effluent being liable to putrefy. Chloride of lime is also a good precipitant; ½ gr. per gallon prevents the growth of fungus and acts as a deodoriser. 22 gr. of lime per gallon has been used at Wiesbaden, and 12 gr. per gallon at Essen; also at Wimbledon, and at Leyton, until the London County Council admitted the Lea Valley drainage to their Barking outfall, and included it in the sewage of London.

Lime and Black Ash Waste.—Lime is mixed with the residue from alkali manufacture and passed into the sewage. The quantity of sludge is increased by the addition of black ash waste, and the effluent is not appreciably affected. This has been tried at Wimbledon,

Lime and Sulphate of Alumina.—Sufficient milk of lime is first added to the sewage to render it slightly alkaline (probably 5 to 7 gr. per gallon is required) and well mixed. A solution of crude sulphate of alumina is then added and the whole well stirred. In the alkaline sewage the alumina is precipitated, and combining with the organic matter forms a bulky insoluble precipitate. In Boston, U.S.A., dealing with tannery refuse, sulphate of alumina, 8 gr. per gallon, was only partially successful. It has also been used at Frankfort.

Lime and Proto Sulphate of Iron.—Milk of lime, in the proportions of 3.7 gr. per gallon of sewage with 1 gr. per gallon of proto sulphate of iron, is used as a precipitant, but the effluent has a disagreeable smell in warm weather. This is in use by the London County Council for the Metropolitan sewage, and it is proposed to deodorise the effluent with manganate of soda and sulphuric acid. It is also used at Worcester, Mass.

International System.—The sewage is screened, and paper and larger solids removed by raking; the precipitant is added at the rate of about 6 to 8 grains per gallon and consists of:—

	per cent.	
Ferrous sulphate	26.64	Analyses by Prof. Roscoe.
Aluminum „	2.19	
Calcium „	3.30	
Magnesium „	5.17	
Combined water	8.20	
Moisture	24.14	
Silica	11.35	
Magnetic oxide of iron	19.01	
	100.00	

This precipitant is called Ferrozone, and after receiving it the sewage is caused to flow along open channels fitted with mixing baffles and scum boards, to tanks where the impurities are allowed to settle for three to four hours. It is then drawn off on to filters composed of sand of varying gauges, and Polarite—a material having the property of absorbing and giving off oxygen—and of the following constituents:—

	per cent.
Magnetic oxide of iron	53.85
Silica	25.50
Lime	2.01
Alumina	5.68
Magnesia	7.55
Water with trace of carbon	5.41
	100.00

The effluent obtained contains very little suspended mineral or organic matter, and about 6 gr. per gallon of free ammonia, albuminoid ammonia, and chlorine. The amount of sludge is in the ratio of 1 to 2.46, to that produced by the lime process. The system has been used at Acton, Huddersfield, Royton, Southampton, Swinton and Hendon. It has now been abandoned by the Syndicate in favour of intermittent bacterial treatment on polarite beds, in use at Melton Mowbray, Chorley, Southwold and other places. I have used this process in several small installations with varying success; the objections being difficulty of applying the Ferrozone in sufficiently small quantities, clogging of the filters, and disposal of the sludge. I have now abandoned this system in favour of bacteria beds.

THE A.B.C. PROCESS (SELLERS PATENT).—A mixture of:

Alum	600	parts
Blood	1	,,
Clay	1900	,,
Magnesia	5	,,
Manganate of potash	10	,,
Burnt clay	25	,,
Chloride of sodium	10	,,
Animal charcoal	15	,,
Vegetable ,,	20	,,
Magnesian limestone	2	,,

in the proportion of 28 gr. per gallon is added to the sewage. The blood is now discontinued. The clearance of the sewage is more perfect than with lime alone, and the phosphoric acid is removed. The objections to other lime processes hold good with this, and the cost is greater. The manure obtained from the sludge is superior to that from lime processes. It has been used at Kingston on Thames and Aylesbury.

SULPHATE OF IRON—applied in direct proportion to the amount of putrescible matter to be dealt with is said to deodorise the effluent and precipitant.

ROCKNER ROTH SYSTEM.—This employs lime and sulphate of alumina for precipitation. The process is carried out in closed receivers, the incoming mixture of sewage and chemicals being slowly forced upward by atmospheric pressure through the precipitant. The effluent is drawn off at the top, and the sludge at the bottom; greater economy of chemicals is obtained, and a more valuable manure produced from the sludge.

SULPHATE OF ALUMINUM AND SILICA WITH LIME—has been used at Hallé, the gases produced being burnt in a furnace.

HILLE PROCESS.—A solution composed of

Chloride magnesium	$1\frac{1}{2}$ gr.
Lime	7 to 9 grs.
Carbonated creosote	$\frac{1}{10}$ gr.

per gallon of sewage, is a variant of the last mentioned.

Sterilising Processes. The Amines Process.—Lime and herring brine, in the proportions of 30 to 50 gr. lime and 3 gr. brine, are mixed together, and the volatile matters produced, composed of amines and ammonia, are passed into the raw sewage. It is claimed that complete sterilisation takes place. It has been tried at Wimbledon.

Electrolysis, Webster's Process.—Iron plates or electrodes connected with the positive and negative terminals of a dynamo, are placed in a channel through which the raw sewage flows. The action of the current upon the chlorides present in the sewage entirely splits it up. At the positive pole the chlorine and oxygen given off combine with the iron to form a salt, which is probably hypochlorite; at the same time carbonate of iron is assumed to exist in the sewage, which deodorises the fæcal matter by removing the sulphuretted hydrogen, and also acts as a carrier of oxygen from the air, by being alternately reduced to ferrous, and oxidised back to ferric oxide. The process depends on the production of certain chemical salts, and the continuous formation of the iron oxides in their nascent state. It adds but little to the bulk of the sewage, and limits the quantity of sludge to the lowest amount consistent with the removal of the supended solids. It has been tried at Crossness (London) and Bradford, and has removed about 70°/$_0$ of the putrescible and noxious portion of the sewage, at the same time removing all living organisms.

AVERAGE COMPOSITION OF BRADFORD SEWAGE.

	Before treatment.	After treatment.
Total solids	127 gr. per gal.	66 gr. per gal.
After ignition	69 do.	47 do.
Loss on ignition	58 do.	19 do.
Chlorine	10 do.	9 do.
Free ammonia	32 parts per million.	21 parts per million.
Albuminoid ammonia	15 do.	5 do.

At Bradford the sewage has also been precipitated chemically by ferric sulphate, but in addition to the large quantity required, and the unsatisfactory nature of the effluent, the very large amount of grease in the sludge obstructs the filter presses and renders it impossible to reduce the water below 95 or even 98°/$_0$. A twenty-five tons sample of Bradford sludge was experimented on at Roubaix by the process invented by M. Delattre, which had proved successful with greasy sewage. Twenty-two and a half tons of sludge, after the addition of sulphuric acid to set free the saponified grease, was passed through the apparatus in twenty-eight hours, the result being $15\frac{3}{4}$ cwt. of filter press cake containg 27°/$_0$ of moisture, and $5\frac{3}{4}$ cwt. of grease containing 11°/$_0$ of foreign matter. The grease was washed from the sludge with benzine (subsequently recondensed) and was valued at £9 a ton. The objection to the system is that it is only applicable to very dense sludge.

The Hermite Process.—Sea water is decomposed by electrolysis, producing a liquid disinfectant which is almost odourless and leaves no deposit; it is introduced into the raw sewage as fast as it is made, dissolving the solids and rendering the organic matter innocuous, but does not remove them. The resultant liquid is odourless, does not readily decompose, and contains little else besides the disinfectant and a little phosphates. The objections to the process are the fact that common newspaper rapidly weakens the fluid, and soap or domestic waste has the same effect, destroying its efficiency by causing the entire contents of the sewer to rapidly appropriate the chlorine strength of the disinfectant. On the other hand, if the chlorine be in excess when its action is complete, it is not admissible to pour an effluent containing free chlorine or its equivalent into watercourses. The method is an expensive one. The effluent is not absolutely free from micro-organisms, but is practically sterile; colonies of the *bacillus coli communis* are absent, and it is probable that the baccilli of typhoid and cholera would not survive. A strength of from 0.5 to 0.6 grammes of chlorine per litre is all that is considered necessary for sterilizing sewage.

The Andeney System of Oxygen Purification—comprises:

1. The use of crude manganese compounds for clarification and precipitation.
2. The recovery of the chemicals employed for precipitation.
3. The use of nitrate of soda as a substitute for air for supplying oxygen to the organisms in the manner required for them.

If the effluent be passed through properly constructed beds, nitrification is obtained without the expense of this last chemical.

Biological Processes.—A partial recognition that natural purification of organic matter was due to living organisms was arrived at early in the present century, when Caignard de la Tour discovered that yeast was a living plant, and Schwann demonstated that putrefaction was due to something in the air that heat could destroy. It was suspected, therefore, that organisms were the actual cause of decay and putrefactive change. Pasteur proved that fermentation did not take place in the absence of living organisms, which he divided into two classes: the ærobic, or thriving in presence of oxygen, and anærobic, or growing without it. Koch and a number of other observers have since elaborated the life history and character of these germs. E. Frankland in 1872 pointed out that a "filter must not be considered as merely a mechanical contrivance, the process carried on being also chemical." The necessity of the co-operation of organic life was ignored until the researches of Warington, P. Frankland, Schloesing, Winogradsky and others, resulted in the isolation of nitrifying and denitrifying organisms, and the Berlin Sewerage Commission reported that nitrates were formed by organisms present in natural sewage and soil. Muntz, Muller, Marie Davy, and others, also demonstrated how the purification of sewage was accomplished by bacterial action. Sorby in 1883, Dupre in 1884 added to the knowledge of the subject, and in 1887 Dibdin stated that "as the very essence of sewage purification is the ultimate destruction . . . . of the undesirable matters, it is evident that an antiseptic process is the very reverse of the object to be arrived at."

In the same year the Massachusetts State Board commenced their well-known experiments on sewage purification by intermittent filtration, with the aid of ærobic bacteria, and established the fact that a filter bed could not be worked continuously, owing to deficiency of æration. This explains the partial failure of the "Ducat" filter introduced in 1897, which has its walls composed of perforated tiles or drain pipes laid horizontally, providing for the admission of air to the filling material continously. This filter was in use at Hendon and experimentally at Sutton, and has been abandoned at the latter place in favour of intermittent treatment in solid walled beds. In 1891 the London County Council determined on a series of experiments at Barking outfall, which will be referred to in detail later. In 1892 Scott Moncrieff introduced his "Cultivation Filter," a bacterial system founded on the following recognised truths:

1. That bacteria under favourable conditions are capable of indefinite multiplication.

2. That there exist in sewage, bacteria which are capable of peptonising solid organic matter, or, in other words, of preparing it by a process comparable to that of digestion for its final disintegration.

3. That in nature the purification of the refuse of the organic world is affected by the life history of these or similar micro-organisms.

In his system the raw sewage passes into the bottom of a bed filled with flints, on a false bottom, and rises through successive layers of gravel, coke, and sand, leaving on its way the solid portions and suspended matters to be dealt with by bacteria. The effluent then passes along nitrifying channels filled with coke. Later he introduced trays filled with materials of varying character and size, which were capable of interchange of position, with a view to submitting the effluent to different colonies of nitrifying bacteria in proper sequence—this sequence to be ascertained by experiment.

In 1893 Lowcock's system was tried at Malvern, in which air at a pressure of four and a half inches of water was forced into the body of a gravel bed, either continuously or at intervals. The same was also tried at Wolverhampton with a coke bed.

In 1894 Waring installed a system at Newport, New York, in which the sewage passed:

1st. Through a settling chamber for removal of mineral detritus.

2nd. Through a shallow bed of coarse broken stone, one of two beds being used alternately, and air pumped into the empty one between charges.

3rd. Through four straining tanks filled with stones and gravel, which on becoming clogged were emptied in rotation, and air forced in until the remaining sludge was destroyed by ærobic bacterial action.

In 1894 burnt ballast beds were started at Sutton, and in 1895 CAMERON introduced the anærobic or "Septic Tank" system at Exeter. Here after a preliminary sedimentation in a chamber where road grit is retained by a submerged wall, the raw sewage is slowly passed through a covered tank containing nothing but sewage; it remains in it about twenty-four hours, during which time it becomes mixed, and a leathery scum forms on the surface which renders the whole anærobic. Below this is a zone of fermentation kept in a state of quiet admixture by bubbles of gas, and at the bottom of the tank, a layer of peaty matter which Rideal in 1898 found to contain about 68°/₀ of mineral matter, 32°/₀ organic and 2.4°/₀ of nitrogen. This peaty deposit does not perceptibly increase. The organic matter is gradually broken up by the bacteria, is raised by the gases, and gradually carried off in the flow.

(I have recently constructed an installation where the septic tank is in the open air, and without a cover, the scum above referred to being sufficient to preserve anærobic conditions). The flow through the tank is continuous. At the outlet end, the liquid, now relieved of most of the solid matters, flows over an ærating weir on to ærobic beds of coke breeze or clinker, four of which are used at a time and one kept in reserve. By automatic gear the beds are filled, rested full, emptied and rested empty for aeration, in rotation. The efficiency is not affected by manufacturing refuse.

In WHITTAKER & BRYANT'S system, as tried at Accrington, the effluent from a lime-precipitated sewage is passed continuously on to coke beds, together with a small jet of steam to maintain the temperature; air is introduced to the bed through drains at the bottom. Similar attempts at so-called continuous filtration were made with the "Noton" shelf filter, and the "Ducat" filter, but were unsuccessful. The various eminent scientific men engaged in the conduct of experiments with bacterial purification, while doing excellent work with a thoroughness and patience that is to be commended, appear to be striving to obtain more than is necessary in an effluent that shall be chemically pure and free from micro-organisms, in fact equal to or better than drinking water. It is admitted that drinking water must contain a certain number of micro-organisms, and that absolutely pure water, such as distilled water, is not suitable for drinking purposes. Similarly, an effluent, to be practically innocuous, should fulfil the following conditions:

It should be inodorous, colourless, and incapable of subsequent putrefaction.

It should not contain organisms of a pathogenic nature in any considerable numbers, or solid matters in suspension.

The following table gives the standard maximum of impurity permissible in 100,000 parts by weight of liquid effluent, adopted by the Rivers Pollution Commissioners, and Thames Conservancy.

RIVERS POLLUTION COMMISSIONERS STANDARD.

In suspension.		In solution.					
Dry mineral matter.	Dry organic matter.	Organic carbon.	Organic nitrogen.	Any metal except calcium, magnesium, potassium or sodium.	Arsenic.	Chlorine.	Sulphur as SH_2 or sulphate.
3	1	2	0.3	2	0.05	1	1

THAMES CONSERVANCY STANDARD.

	Not exceeding in 70,000 parts	Not exceeding in 100,000 parts
Suspended matters	3 parts.	4.3 parts.
Total solids	70 ,,	100.0 ,,
Organic carbon	2 ,,	3.0 ,,
Organic nitrogen...........	0.75 ,,	1.1 ,,

Bacteria Beds have been constructed that will produce an effluent of this description from average sewage, and at the same time do away with the sludge or precipitated organic matter. Mineral suspended matter does not present any difficulty if it is kept out of the beds by preliminary rapid sedimentation. Long and severe frosts have not been found to interfere with the efficiency of the beds. The results of work done with crude domestic sewage at Sutton, and at Barking and Crossness with the sewage of London (which contains manufacturing refuse of a most varied description), have been carefully recorded and examined by expert chemists and bacteriologists, whose reports, with a few reservations on biological matters, are unanimous in approval of the bacterial treatment pure and simple. By these reports it has been established that sewage contains all the organisms necessary for its decomposition and final purification ; all that has to be done is to discover the best and most practical way of allowing the natural purification to take place without nuisance or danger. Putrefaction is brought about by the action of bacteria, some ærobic, others anærobic. Dead organic matter decays as the result of the vital activity of bacteria, and ammonia is liberated. The nitrifying organisms bring about the oxidation of the ammonia, first to nitrous and then to nitric acid. These acids, by reaction upon the bases, always present, form nitrites and nitrates, which nourish the living plant. While the nitrogen is undergoing these changes, the carbon of the organic matter is converted into carbonic acid, and the hydrogen mainly into water. To some extent also the nitrogen and hydrogen are liberated in a gaseous state.

Organic matters found in sewage are partly in suspension and partly in solution. The aim and object of biological treatment is to render soluble by microbial agencies the solid matters, and to split up both the matter thus dissolved, and the organic compounds which were originally in solution, into their simpler elements ; these substances should then undergo oxidation induced by the life processes of nitrifying organisms, and an effluent be produced which is free from putrescible matter, and contains only inorganic or mineral substances. The removal of suspended matter or organisms by mechanical filtration is not the object of the bacteria bed, and the introduction of matters inimical to bacterial life is to be avoided.

Bacilli experimentally introduced into crude sewage shewed that the cholera bacillus and *staphylococcus pyogenes aurus* are able to exist in it for a considerable time, but *micrococcus prodigiosus* dies in ten to sixteen days. Bacteria, spores of ærobic bacteria, liquefying microbes, *bacillus coli* and spores of *bacillus enterditis sporogenes,* have been found in lesser numbers in the Barking effluents than in the raw sewage; but the reduction is not well marked, and in some cases the effluent contained more micro-organisns than the raw sewage.

While the chemical results at Barking were always satisfactory, the bacteriological results were usually quite the reverse; because the microbes producing the chemical changes passed through the beds in practically unaltered numbers. Nevertheless, the beds effect a reduction of 80 per cent. of the dissolved oxidisable and putrescible organic matter in raw sewage, as compared with 17 per cent. effected by chemical treatment. The effluent is non-putrescible; the suspended matters in crude sewage are *entirely removed* by biological treatment, whereas chemical methods only remove about 80 per cent, and no sludge is produced. The enormous saving of expense by the elimination of this, the greatest difficulty, is sufficient to carry a verdict in favour of the system, apart from the abolition of chemicals and their application, and the reduction in the area of land required for disposal works.

Dr. Houston concludes his report on the biological treatment of London sewage with the following rather discouraging statement:—" Only one conclusion seems possible, namely, that however satisfactory the process may be from the chemical and practical point of view, *the effluents from the bacterial beds cannot be reasonably assumed to be more safe in their possible relation to disease than raw sewage slightly diluted, but otherwise unaltered in its bacterial composition.*"

This is the deliberate opinion of a man who has thoroughly studied the question, but with perhaps a bias due to his view being taken, so to speak, through the tube of the microscope instead of the larger tube of the drain pipe, as an engineer might be expected to examine results.

The results obtained at Sutton from beds formed of burnt ballast, broken granite, roofing tiles, crockery, slates, and other materials, have been widely published and discussed, and are eminently satisfactory. I have put down a set of beds at Ightham, Kent, which were started in May 1900, and take the whole of the sewage and slop waters from a large house, stables, and lodge. They have been in constant use since the start and are entirely automatic.

The raw sewage is delivered by a 4 in. drain with a fall of 1 in 40 through a vertical right angled junction into a small settling tank (No. 1), holding one day's flow; the vertical pipe prevents the breakage of the scum which forms on the surface, and has the appearance and odour of peat. The paper, etc., being delivered below the surface rises under the scum out of sight and is gradually broken down and disappears altogether; any mineral matter is deposited on the bottom. From this tank the liquid overflows by a similar pipe on to a bed (No. 2) composed of 1 in. Kent ragstone. When this bed is full it starts a syphon and is completely emptied into a bed (No. 3), composed of $\frac{1}{4}$ in. Kent ragstone, No. 2 being ærated until again filled by the sewage. One charge of No. 2 bed is sufficient to fill No. 3, and a drip tap placed near the surface of No. 3 permits a little of the liquid to escape into a small tank (No. 4) containing a syphon. By opening or closing this tap, the time during which No. 3 stands full can be regulated to a nicety (two hours is found sufficient), and on No. 4 becoming full the syphon starts and empties No. 3 into the effluent drain, through which it is discharged into a small fish pond, where fish live apparently uninjured, and from this overflows into a neighbouring ditch.

The only attention this plant has required since the start has been the clearing out of No. 4 tank syphon, which had become blocked with fine sand washed out of the material, and the removal of a luxurious crop of grass which interfered with the æration of both No. 2 and No. 3 beds. The material has been stirred up and raked over without nuisance, in fact only an earthy and not unpleasant odour is perceptible. No. 1 scum tank has disposed of all the paper and vegetable matter, and no odour can be perceived on stirring this up through the inlet or outlet pipe. The mud at the bottom does not exceed one inch in depth; the under drainage of the beds has not choked, and the beds themselves have no sludge in them. The effluent is clear, and from No. 3 inodorous; that from No. 2 has a slight odour of sulphuretted hydrogen. It may be fairly expected that the action of the beds will continue to improve, as they take some months to attain to their maximum efficiency. The keeping qualities of the effluent have been practically demonstrated, and for all practical purposes the beds are a complete success. A sample of the effluent taken in February, 1901, has been kept near the fire uncorked for more than two months. At first it gave off a slight odour on being shaken which disappeared in five days; it was in October, 1901, quite odourless, colourless, and clear with the exception of a fungoid growth of about .01 per cent.

The fact of no attention being required is important; so many small installations fail through neglect and irregular supervision that an automatic plant becomes a necessity. When dealing with large quantities of sewage it is not so essential to have automatic apparatus, except for avoiding night work, as it is necessary to employ a man to clean out the tanks, or catch-pits, that intercept mineral matters, to take samples, and keep records. During the day there is usually such spare time, and it is better to let the attendant open sluices, and so keep him regularly employed, than to use syphons or tippers. Sewage constantly varies in composition from hour to hour, and it is only by continuous observation that the correct time can be ascertained during which it is necessary to hold up the sewage in the beds, and subsequently to let them stand empty for æration. It has been found that better effluents are produced by hand-filled beds than by those automatically controlled.

The Fourth Report on the Experimental Treatment of London Crude Sewage by Dr. Frank Clowes was published on April 17th, 1902. It describes the results obtained from four years' experimental purification of the effluent, and contains conclusions of the greatest importance. Dr. Clowes says: "I have had in constant operation, and under most careful observation, a series of coke beds, supplied with raw sewage direct from the sewer. The raw sewage which has been screened from coarser matters only, is pumped continuously into a settling tank, the rate of supply being so adjusted that the sewage remains about six hours in the tank before it flows away through an elbow pipe from beneath the surface of the liquid into the coke beds. In this tank practically the whole of the suspended or floating particles of the sewage settle as sludge, and are allowed to remain undisturbed. More than 50 per cent. of this sludge was removed by bacterial action, the portion which disappeared being the most putrescible portion of the sludge. The sewage, as it leaves this tank, is less pure than the effluent at present discharged into the Thames at Crossness (*i.e.* the chemically treated effluent), and is quite unsuitable for direct discharge into the stream. By the subsequent coke bed treatment it is rendered sufficiently pure to support the life of fish, and is insured against undergoing any offensive change, even in summer time. The settled sewage is allowed to flow into the coke bed, which is a tank filled with suitable coke fragments to a depth of six feet. As soon as the bed is filled to the surface of the coke the supply is stopped, and the liquid is allowed to remain in contact with the coke for two hours. It is then drained off from the bottom of the bed and constitutes the "bacterial effluent." The bed remains empty for two hours, and is then refilled with a fresh charge of sewage which is treated in precisely the same way; thus the bed receives and purifies four charges of settled sewage in the twenty-four hours—allowing one hour for the operation of filling and a similar time for discharging."

The conclusions arrived at are:—

1. That by suitable continuous undisturbed sedimentation the raw sewage is deprived of matter which would choke the coke beds, and the sludge which settles out is reduced in amount by bacterial action to a very considerable extent. The reduction might undoubtedly be increased by the preliminary removal of road detritus.

2. That the coke beds, after they have developed their full purifying power by use, have an average sewage capacity of about 30 per cent. of the whole space that has been filled with coke.

3. That the sewage capacity of the coke bed, when the bed is led with settled sewage, fluctuates slightly but undergoes no permanent reduction; the bed does not choke, and its purifying power undergoes steady improvement for some time.

4. That coke of suitable quality does not disintegrate during use.

5. That the "bacterial effluent" of settled sewage from the coke beds does not undergo offensive putrefaction at all, even in summer heat, and can never become offensive, and that this effluent satisfactorily supports the respiration of fish.

6. That the use of chemicals is quite unnecessary under any circumstances, when the above method of treatment is adopted.

He goes on to recommend the adoption of the system on a gradually increasing scale until the whole of the London sewage is treated. The report then deals with the results obtained from no less than forty-seven separate towns, some of which sent in most exhaustive data of experiments conducted on these lines. A careful consideration of the information obtained from the various centres where bacterial treatment has been tried shows that the process has been uniformly successful when the construction and use of the necessary plant has been reasonably and properly carried out. The only exception that appears possible to this general statement is interference which is caused by the sewage being of a very unusual character.

The third report of the Commissioners appointed in 1898 to inquire and report as to the methods which may properly be adopted for treating and disposing of sewage was issued last April and, as at least two or three years will elapse before the final report appears, it may be useful at this stage to consider the evidence which the Commissioners have already accumulated, and the conclusions to which this evidence has led.

I have extracted the following from a *precis* which appeared in the *Builder* of July 25th, 1903. The "artificial" process of purification, commonly known as the bacterial system, was carefully inquired into by the Commissioners, and its value was demonstrated by many witnesses, although clear evidence on a number of points was not forthcoming. The possibility of pathogenic organisms passing through the filters is one of the questions about which the Commissioners were not satisfied. The three conclusions published in the Interim Report of July 12, 1901, are of great importance, and have already led to a modification of the Local Government Board's practice. We give them in a condensed form:—

1. "We doubt if any land is entirely useless . . . . we are, however, forced to conclude that peat and stiff clay lands are generally unsuitable for the purification of sewage; that their use for this purpose is always attended with difficulty; and that where the depth of top soil is very small, say, 6 in. or less, the area of such lands which would be required for efficient purification would, in certain cases, be so great as to render land treatment impracticable."

2. ". . . . We are satisfied that it is practicable to produce by artificial processes alone, either from sewage, or from certain mixtures of sewage and trade-refuse . . . . effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance. . . ."

3. "We consider it of the utmost importance that the simplest possible means should be provided for adequately protecting all our rivers; and we are further of opinion that it will be desirable, probably for some time to come, that scientific experiments should be carried on in order to ascertain all the real dangers of pollution, against which they should be protected."

In conclusion I quote from George Vivian Poore's essays on rural hygiene some axioms which are peculiarly suitable to Hongkong. The italics are mine. "Excrement is the only ingredient of sewage against which dangerous infective properties have been proved again and again. It is the ingredient which, *when mixed with water*, finds its way to our drinking water, and causes Typhoid and Cholera. Sewage without excremental matters is, doubtless, offensive, and is probably unwholesome in many ways, but it stands in the position of a suspect rather than that of an habitual criminal against whom no end of previous convictions have been proved. If excremental matters were stopped out of our house drains, we could in country places often have recourse to the old practice of allowing our household slops to run in open gutters, concerning the ventilation of which there could be no doubt, and the gutters might be subjected to the wholesome discipline of a broom, and the purifying influences of sunlight and drying winds. If excremental matters be stopped out of the house drains, the total volume of sewage to be dealt with would be diminished by, at least, one fifth. . . . Typhoid was not recognised in this country (England) until the water closet became common. There is no doubt whatever that wherever excrement is mixed with water we are in danger of typhoid. Sewage being a nuisance, although a necessity, it is to our interest not unnecessarily to increase its quantity or its offensiveness. Excrement should be kept out of the drains, for by doing this the putrefaction of the solid is prevented, and the purification of the liquid by filtration through the earth is effected with ease which is proportionate to the thinness of the fluid. All solid matter should be removed *every day* from the immediate neighbourhood of the house and buried in the *top layer of cultivated ground.* Household slops should be poured on the surface of the *garden*, and the mistake of attempting what is known as subsoil irrigation must not be made."

"One of the reforms most urgently needed *is the supply of water by meter.* The possession of water under pressure is a priceless boon not to be abused, and the only way to stop the abuse of water is to charge for it in proportion to the quantity used. . . . The charging for water by rateable value is most inequitable. . . . All water closets which discharge into a public sewer should be taxed. Those who make *no contribution of foul water* to a public foul water sewer, should not be called upon to pay for its construction or maintenance, provided that their sanitary arrangements be satisfactory and not likely to cause annoyance or danger to neighbours. All sewers and sewage works should be constructed and maintained entirely out of rates levied on the ground landlords; because it is they, and they only, who make a profit out of that overcrowding of houses on space which is only rendered possible by sewage schemes, and which is too often the main reason for their inception. The pollution of rivers ought not to be tolerated, and the Act for its prevention most certainly ought to be enforced against individuals."

"All manufactories should be compelled to deal with their waste products, and should not under any circumstances be allowed to discharge factory waste of any kind into public sewers or streams. . . . They should not be allowed to get their effluent purified *at the expense of the ratepayers.* If manufacturers were compelled to deal with their own refuse . . . . the factories would almost certainly be compelled to occupy more space than they do at present, and this rule, which seems equitable and reasonable, would have the effect not only of saving the ratepayer's pocket, but of checking that excessive overcrowding which is such a danger to the health of towns."

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HOUSE DRAINAGE

By J. J. BRYAN

THE subject of house drainage is one which deserves more serious attention than is often given to it. It is beyond dispute that water-mains and wells becoming polluted by infected leaky drains will spread certain diseases, such as typhoid and cholera, and possibly others, either directly by means of the water or indirectly by polluting food or vessels washed in the water; but it is disputed that infected drains can aerially convey infection, although medical men agree that drain air will produce sore throat, and contaminate milk and other food and probably render it harmful. The epidemic of typhoid fever at Maidstone in 1897, according to the Local Government report, was due to the water supply being polluted by drainage.

Dr. Thorne Thorne in a report to the Local Government, dated 1896, states that the death rate from typhoid in England and Wales has been gradually lowered as the drainage of towns has been improved, it being 0·38 per 1,000 in the seventies, and 0·17 at the time of the report.

In a climate like Hongkong, the decomposition of sewage sets in very quickly, probably reaching its most active stage in from twelve to twenty-four hours, according to the time of year. At this stage very foul gases are given off, and by chemical analysis the following have been found: sulphuretted hydrogen, marsh gas, bicarburetted hydrogen, carbonic acid, and traces of ammoniacal gas. It is therefore essential that the sewage should be removed from a building in the quickest manner possible, and that the system for such removal shall be free from defects caused by bad design, unsuitable materials, or careless workmanship.

Our local ordinance does not define sewer and drain. Generally speaking it may be said that sewers, as understood here, are owned and maintained by the Government, and drains by private individuals. In England it is a disputed point as to where the drain ends and the sewer begins. It would be advisable for the students to look up the definition of "sewer" and "drain" as given by the Public Health Act of 1875, and the Public Health Amendment Act of 1890, also the reports of law cases bearing upon this. Three of the most instructive are Travis *v.* Utley, when the Corporation of Halifax sued the owner of three houses for the costs incurred in reconstructing the drains; the Shoreditch Board of Works *v.* the owners of Norfolk Place; and the Strand Board of Works *v.* the owners of the Lowther Arcade. We might define a house drain as being a channel (either open or closed), which conveys liquid refuse from a house to a sewer or cesspool, together with any solids that may be in suspension in such liquid refuse. A sewer would be a similar channel into which two or more house drains discharge. It is unnecessary to go into any description of brick or stone drains; they are expensive to construct, cannot be made permanently air and water tight, and they lend themselves to the formation of deposits on their interior surfaces.

Drains in all modern work are formed of circular pipes, either of earthenware or iron, and are made in various sizes from two inches to two feet. The points to be observed in choosing earthenware drain pipes are—they should be perfectly straight, regular in thickness, true in section, free from fire cracks, well glazed inside, non-porous, and made in one piece. If the barrel and socket are made in separate pieces it often happens that when subjected to an hydraulic pressure a leak occurs at this point. Pipes made from clay which will only stand a low temperature are inferior to those burned at a high temperature. If the glaze can be picked off it is proof that the pipes are made out of clay that would not stand a high temperature. The outside of the spigot end and the inside of the socket should be roughed, so as to afford a key for the jointing material. The socket should be of sufficient depth to allow of the spigot entering at least one and a half inches. They should be, as far as possible, impervious. To test for this the pipe should be thoroughly dried and weighed, then put into water for twenty-four hours, taken out, wiped and re-weighed. The one which has taken up the least amount of water is the best pipe. If a pipe is required to be cut it should be stood on end and filled with sand. This reduces the liability of fracture.

Table of sizes for earthenware pipes:—

Diameter.	Thickness.	Depth of Socket.
4″	$\frac{1}{2}$″	1$\frac{1}{2}$″
5″	$\frac{5}{8}$″	1$\frac{5}{8}$″
6″	$\frac{5}{8}$″	1$\frac{3}{4}$″
″	$\frac{3}{4}$″	2″

Iron drain pipes are made in various sizes, and in 3 ft., 6 ft., and 9 ft. lengths. Most of the points to be observed in choosing earthenware pipes refer to iron ones also. They should be cast vertically, with the socket end down. This gives greater density at the part where it is most required. The best makers also cast them about 9 ins. longer than is required. This allows for any impurities which may be in the iron to rise to the top, and the extra length is cut off in the lathe. Pipes are often cast with a fillet on the spigot end. This fillet fits on to the shoulder of the socket. Care should be taken, when using these pipes, to see that the alignment is true. When put together there should be a space of about a quarter of an inch to allow for caulking.

Table of sizes for iron pipes :—

Diameter.	Thickness.	Depth of Socket.
4″	$\frac{3}{8}''$	$2\frac{1}{2}''$
5″	$\frac{3}{8}''$	$2\frac{3}{4}''$
6″	$\frac{3}{8}''$	$2\frac{3}{4}''$
9″	$\frac{5}{8}''$	3″

The advantages of using iron pipes for drainage work are :—

(1) They are made in longer lengths, consequently the number of joints is reduced.

(2) A caulked lead joint is stronger and more reliable than any that can be made on a stoneware pipe.

(3) They are much less liable to fracture.

To prevent corrosion, they should be coated with some solution such as the Bower Barff or Augus Smith's. The former method consists of heating the pipes to a high temperature in a chamber, and then turning on superheated steam. This causes a coating of magnetic oxide to be deposited on the surfaces of the iron. The Angus Smith process is to heat the pipes, and to dip them into a mixture of coal tar, linseed oil, and resin. Some makers enamel the inside of the pipes, but this is very liable to chip, especially whilst the caulked lead joint is being made. The unequal expansion and contraction the pipes are subjected to (owing to the difference in temperature of the sewage flowing through them) is liable to crack the enamel. Whichever process is selected care must be taken to see that the interior surfaces of the pipe are free from blisters. When it is necessary to use bends it must be remembered that easy curves only should be used, as the quicker the bend, the greater will be the resistance to the flow of sewage. Never allow a bend to be made with straight pipes, as is often done. Sound joints cannot be made, as the top of the spigot is drawn nearly out of the socket in getting the angle required, and the lower side almost closes up the space required for the jointing material. The flow through the pipes is also impeded. The bends in common use are known as $\frac{1}{4}$, $\frac{1}{8}$ and $\frac{1}{16}$. A true $\frac{1}{4}$ bend should be a curve of 90°, so that four placed together would form a circle. When short branches are required to be brought into the main drain, the connection may be made by a junction. If the branch is a long one, or has a number of inlets, it will be necessary to build a manhole. The construction of these will be dealt with later. The arm of the junction should deliver in the direction of the flow. A right-angled junction should not be used, as they are very liable to become choked, and at the same time check the discharge. It is a common practice for a workman to cut a hole in the side of a pipe in the main drain and insert his branch pipe into it; or if his branch is on a higher level, to save him the trouble of excavating, will run up a small brick chamber, and discharge his branch into it at a higher level than his main. Needless to say neither should be allowed. It is sometimes required to enlarge the size of a main drain. This may be done by building a manhole and forming a tapering channel at the bottom, or by a taper pipe. If a taper pipe is used care must be taken to see that the invert of the last smaller size pipe is in line with that of the first large one. Only the top and sides of the pipe should be tapered, the bottom of the barrel being straight.

All inlets to drains, except fresh air inlets and exhausts, must be trapped to prevent the escape of any foul air which may have accumulated in the drain. A trap may be described as a bend in a pipe which, by retaining water in it, breaks the connection between the air in the two portions of it. The seal is the distance between the level of the standing water and the lower part of the dip. For a disconnecting trap the seal should be not less than 2½ ins. and for a surface trap not less than 2 ins. There are such a large number of traps on the market, that to attempt to describe them and to discuss their several advantages and disadvantages would occupy too much time, so I will give you the points of a good form of trap, and with a little thought you will readily be enabled to criticise them yourselves. It is essential that a trap shall be self cleansing, that is, it should have no corners or angles inside in which filth might collect. The size of the trap, fitted to its own particular duty, should be no larger than will permit of the contents being changed at every flush. This is most particular when choosing traps for fixing under w. c.s, urinals, baths, and lavatory basins. The depth of seal should be as great as possible. The trap should be so formed that the flush is not broken before it reaches the "standing water," but should fall on it with a vertical pressure which has the tendency to drive all foreign matter out of it. Traps may be divided into three classes: those fixed between the house drain and the sewer or between two portions of a drain, called disconnecting traps; those fixed at the inlets to drains in yards, &c., for the reception of slop and rain water, called gullies or surface traps; and those fixed under w. c.s, sinks, or baths which are known as simply traps or plumbers' traps. For the present we will only consider the first two.

One of the first forms used for disconnection was the "Dipstone." They were constructed of brick or stone, with a dip or tongue which entered the standing water in the trap, and was supposed to keep back the foul air from the sewer or cesspool entering the house drain. By looking at the drawing, you will at once see that it in nowise conforms to the conditions I have just mentioned. Solids collected at the bottom of the chamber and there remained until removed by hand; a large proportion of the sewage filtered through the brickwork into the surrounding soil; the cover was seldom airtight and as the interior of the trap was always in a filthy condition, foul gases found a ready access into the outer air. Although pipe disconnecting traps have been in use for more than a quarter of a century, this form of disconnection still exists, and is probably still being used, even in England, by ignorant builders. I received a letter about the end of last year from a consulting engineer in England, who informed me that he had found seven in the course of the last twelve months, all fixed on to the drainage systems of large houses in different parts of the country.

The first form of pipe disconnecting trap was called the "Drain Syphon." By studying the drawing for a moment, and noting the defects in this form of trap, you will the more readily recognise one in which these faults are remedied. In the first place, the outlet is made on about the same level as the inlet and there is no pressure exerted on the standing water; consequently the flow through them is very slow, and the solids are not driven through the trap, but float about in it, portions settling and fouling part marked B. To remedy this the makers tried to improve the trap by forming the cleansing eye marked A. But this only helped the fitting to become more foul, as it provided an additional surface where solids settled. The quantity of water contained in it is much too large—a 6 in. trap of this pattern, with a cleansing eye, holds about eighteen pints, so that the whole of the contents cannot possibly be changed by the discharge of a small sink or lavatory basin. The seal also is much too small and is liable to be destroyed in dry weather by evaporation. Although this form of trap is condemned by all persons having any knowledge of what constitutes drainage on sanitary lines, it is still shown in the catalogue of some firms, and manufactured by them, so that evidently it is still used.

In a lecture I do not care to recommend any particular make, but I should advise you to study the different models I have here, and also the drawings and, bearing in mind the principles which should govern a good trap, choose one for ourselves. Both disconnecting and surface traps should have platforms moulded on to them, so that when fixed they may stand firm. If they are not provided with this platform, they must be firmly bedded in concrete. Care must be taken to fix them perfectly level, so that the seal may not be diminished, or any obstruction caused to the flow through them. I am constantly coming across traps which have been fixed unevenly. In my opinion it is a mistake to fix a 6 in. disconnecting trap on to a 4 in. drain, or a 9 in. on to a 6 in. If the disconnecting trap is larger than the drain it frequently becomes very foul, because the full scouring effect is lost. This is secured by some makers such as BUCHAN, KENYON and HELLYER by reducing the size of the "throat" of the trap. In Hongkong we usually use the ordinary P trap, as this is the only form the local makers manufacture. It makes a better surface trap than one for disconnecting purposes. If it is fixed in a chamber the sewage must be conducted on to the mouth by a channel, and the flow to a certain extent is broken, so that the full scouring action is lost. If no chamber is built, then a shaft must be formed either in brickwork, or by a pipe with a right angled junction. In the first case the brickwork soon becomes saturated with sewage, and the surrounding soil becomes very foul. In the second case at least two extra joints are required, which frequenly get broken, unless surrounded with concrete, which if done, together with the extra labour in fixing, costs as much as a trap of a good pattern, without securing the better results.

In reading text books on the subject of house drainage, you will find that many authorities condemn the use of the disconnecting trap, stating that it causes more nuisance than it prevents. I am yet to be convinced that, providing a trap of proper form and size be fixed, the principle of a disconnecting trap is not a good one. If a house drain is not disconnected from the public sewer, then it practically means that the sewer air is laid on to the house drains, and an imperfect joint, a fractured pipe, or a badly sealed trap, may allow it to escape into the house. It would be especially dangerous to houses which have water closets in them. Often the closet requires some attention: valve closets, for instance, unless very carefully used get out of order and have to be taken away to be repaired. The connection to the soil pipe is often closed temporarily by a wooden plug, which may or may not be air tight. Even when we arrive at a perfect system of sewer ventilation, it is surely better to confine evils that may happen to one house, or even a block of houses, than to run the risk of contaminating every house, which would be the case if their drains were connected direct to the sewers, and the latter ventilated by means of upcast shafts connected to the private house drains. This is a method advocated by some engineers to get over the difficulty of sewer ventilation.

Two of the old forms of surface traps, the "Bell" and the "Lip," were made of iron. Both are almost useless for the purpose for which traps are intended: their water seal is too small to be effective, and they lend themselves to the accumulation of filth on their interior surfaces. In the "Lip" no provision is made for jointing the trap to the drain pipe, and consequently very clumsy and defective connections are made. In the "Bell" the portion which forms the seal and the grating are in one piece. When in use the grating is often removed to allow of the more rapid discharge of the waste water, the result being that a clear passage is left for the drain air. (A drawing of an unsuitable form of pipe trap, and a few models of good forms, were shown and their disadvantages and advantages discussed.) As an extra precaution in preventing drain air entering the waste pipes of sinks and baths, the byelaws of many sanitary authorities require that the trap be fixed 12 or 18 ins. away from the waste pipe, the waste water is then conducted on to the trap by a channel formed in cement, or by an earthenware block with channel formed in it, and fitted with a flange underneath made to fit into the mouth of the trap. The disadvantage of this arrangement appears to be that the full force of the flush is lost, and the scouring effect lessened. To obtain this a trap with a side inlet may be fixed, and the waste pipe brought into this inlet and made to discharge under a grating which should be fixed over the mouth of all surface traps to prevent solids entering them. There is, however, the danger of drain air entering the waste pipe, if the seal of the trap is destroyed. If it is necessary to fix a trap under cover, or in a position where its seal is liable to be destroyed, such as near a flushing tank, or in an engine house, the trap must be made to discharge on to another trap which is fixed in a safer position, or what is better still, convey the water off by a surface channel to the nearest trapped drain inlet.

In designing the drainage for hotels or large houses where much cooking is done, some arrangement for either collecting the grease, or breaking it up and sending it rapidly through the drain, must be devised. The body of water contained in an ordinary surface trap is too small to cool and solidify the grease which is discharged from such a building, and it is passed into the drain in solution, to ultimately cool and adhere to the sides of the pipes. Grease traps can hardly be called a sanitary fitting, because they are not self cleansing, but if regularly attended to they save a great deal of trouble by preventing the continual choking of the drains with grease. One of the models I have here provides that a large body of water is always in the trap. Both the inlet and outlet are well below the water line, so as to prevent their becoming fouled by the grease. As the grease in solution becomes cooled in its passage from inlet to outlet, it rises to the surface and is solidified. These traps should be thoroughly cleaned out at least once a week. Unless you can depend on the grease being regularly removed, and providing the water authority will allow it, it is better to fix a trap with a flushing rim, similar to model, and connect an automatic flushing tank to it. This form of trap may be set in a brick chamber, as sketch, with a ventilated iron cover, or it may be fixed without any brickwork. The flushing tank should contain about twenty gallons, and be fixed at least five feet above the trap. With this head, a 3 in. flushing pipe is sufficient; but with a less head either a larger tank or a 4 in. flushing pipe must be fixed.

We will now consider the different joints used is drainage work. The sanitary condition of a drainage system depends very largely upon the soundness of the joints. They should be perfectly air and water tight to prevent the leakage of any sewage, or the escape of gases.

When socketed pipes were first introduced clay was the material used for jointing them, and this joint is still used in many country districts in England. The arguments urged in their favour are that they give if there is any settlement in the ground, and they are much easier to disconnect than a solid joint, if a new length of pipe is required to be sprung into an existing drain. In the first place there should not be any settlement, and the second argument only proves how weak the joint is. It is liable to be washed out by the liquids contained in the drain and the surface water that may percolate down to it. It is also liable to be destroyed by worms and the roots of trees. Lime mortar is not a situable material for jointing drain pipes. It quickly wears away, and it is not impervious. A carefully made cement joint is a good one, and I have tested such joints by an hydraulic test, after they have been laid for more than six years and found them sound. To make a good cement joint it is advisable to mix the cement a short time before it is wanted. If mixed and used immediately it is liable to crack, especially if it is neat. I prefer it mixed in the proportions of two parts cement to one of clean sharp sand. A piece of hemp, long enough to wind twice round the spigot end, and thick enough to fill the space between the socket and the pipe, should be saturated with grout cement and placed round the spigot of the last laid pipe and caulked up to the shoulder of the loose pipe. The space left is then filled in with the stiff cement, already mixed, by pushing it well in with the fingers, particular attention being paid to the under part of the joint, as it is usually there where a leak occurs, owing to the workman not being careful to see that his fingers meet, when pushing the cement home. Directly this is done the inside of the pipe should be carefully wiped, so that any cement which may have squeezed through may be removed before it has time to set. This is usually done by means of a disc, made of wood or leather, fastened on to a stick 2 ft. 6 ins. long. A special form is sometimes used called a "badger." It consists of two discs of wood, with india-rubber bands round, connected together by a spiral spring. This facilitates the passage through the bends. If the hemp is not saturated with the grout cement before being caulked in, it is liable to decompose and leave a space into which sewage may collect. It also weakens the joint. If it is left out altogether the pipe frequently drops and a perfect alignment is not maintained. The cement should be trowelled off as shewn in sketch.

I regret that I have not had an opportunity of testing any patent joint after it has been in use for any length of time, so cannot speak as to their durability. Most of the patent joints consist of rings of a composition made from sulphur, sand, and tar, moulded on to the spigots and sockets. When the pipes are put together, these rings fit against each other and form the joint. The composition is usually well greased before the pipes are put together. Some of them are liable to become loose owing to the expansion and contraction they are subjected to, caused by the different temperatures of the sewage. The rings also are likely to be chipped whilst the pipes are on the works, and before they are put together. In STANFORD'S patent the rings are wedge shaped. DOULTON'S was, I believe, intended to be an improvement on STANFORD'S. The composition is rounded so that when the pipes are fitted together a ball and socket joint is formed. This is to allow for any settlement that may take place. In HASSAL'S joint, the rings fit against each other, but a space is left into which cement is poured. In Archer's joint also a space is left similar to Hassal's. Syke's patent consists of a wormed composition, and the pipes are screwed together. In addition, a special putty is pressed into the cavity formed in the socket. In Tyndale's "double seal" and Doulton's improved joints, in addition to having rings of composition, the sockets are made extra deep, leaving a space to be filled in with cement. The latest pipe joint is the "Parker." In this joint the composition is cast upon the spigot end only, and is hollowed in the centre, into which liquid cement is poured through an opening left in the socket. In making the joint a fillet of clay is placed round the outer rim of the composition, in order to prevent the escape of any cement.

Most of the pipes fitted with these patent joints are selected and tested before leaving the works, and when carrying out work where expense is not the first thing to be considered their use should be recommended; but for ordinary house drainage work in Hongkong they are too expensive. Personally I should prefer to use one in which cement is used in conjunction with the composition. They are very useful when laying a drain in water logged ground, as most of these joints can be made under water. For iron drain pipes the joints should be made by caulking rings of hemp, soaked in red lead, into the space between spigot and socket, until it is about a quarter full. Care should be taken that the hemp is placed evenly round the pipe, or it will be out of centre. Melted lead is then run in until it projects slightly above the face of the joint. The lead should be well caulked home by a caulking tool, and when finished should be flush with the top of the socket. Some workmen use rings of cold lead instead of the hemp, but this is not to be recommended, because the hot lead when poured in, partially melts portions of these rings, and the result is that a perfectly solid joint is not made.

Screw joints, and those made with hemp and red lead only, should not be allowed for drain pipes. Some sockets are cast with a groove running round the inside or from the top to the shoulder. This forms a key for the lead and is supposed to permit of a stronger joint being made, but the groove reduces the thickness of the socket at that part and renders it weaker. For all practical purposes the ordinary caulked lead joint is sufficient, and when carefully made is to be relied on.

All drains should be laid in straight lines, with a uniform grade and on a solid bed. This is not always to be found, and in that case it is necessary to make one. A bed made of puddle clay is not to be depended on. Before commencing to lay our bed we must ascertain our available fall. Levels must be taken by a surveyor's level, or in cases of short lengths may be worked out by means of a straight edge and spirit level. The difference of level between the sewer, or point of connection, and the head of our proposed drain, gives us the available fall. After arranging the grade the trench must be excavated to the necessary depth, care being taken not to dig out more earth than is wanted. The bottom of the trench should then be well rammed and the concrete bed laid down 6, 9 or 12 ins. thick, according to the nature of the ground, and about 6 ins. wider than the diameter of the pipes. Pegs should be driven in every 10 ft. as a guide to the workmen, and wood templets fixed to form dishings for the sockets. Sometimes these are cut after the bed is laid, but it entails loss of time, and every drainage contractor should have plenty of these templets of different sizes in stock. The dishings are required wherever a socket occurs, so that the workman may easily get his hand round when making the joint. They also allow the barrel of the pipe to rest firmly on the bed of concrete, so that any downward pressure the pipe may be subjected to, after it has been laid, will not be exerted on the joint. Frequently pipes are laid resting on their sockets only. The reason given for this is that a leaky joint may easily be detected and made good. Well, so they can by laying them in the manner I have described, and you do not run the risk of having your joints broken after they have been tested and before being covered in, by some careless workman walking on the pipes. You are also sure that there is no space below the body of the pipes, which is frequently the cause of leaky drains, owing to the joints having given way by the pressure of earth and traffic over them.

Attention should be given to the quality of the concrete forming the bed. The stones should be broken to not larger than $\frac{3}{4}$ in. cubes, the proportions measured and mixed in a dry state, afterwards sufficient water being added by a rose to mix them thoroughly. If too much water is added, or it is thrown on from a bucket, the lime or cement is liable to be washed away. The moist mixture should be turned over two or three times, laid down, and rammed to the levels given. The concrete should then be allowed to set before laying the pipes.

There are several small but important details to be looked for and insisted on being carried out, if your work is going to stand the test of time and be a credit to you. If the bed has been properly graded the laying of the pipes is much simplified, and does away with the objectionable practice workmen have of getting the fall to the drain by inserting pieces of brick or stone under the sockets. These are liable to give and cause the joint to break. A common way of laying drain pipes is by means of a straight edge with a screw inserted at the bottom on the under side equal in length to the fall required in the length of the straight edge. Or a piece of wood is fastened to the straight edge. This screw or gauge frequently becomes loose, and an error made in one pipe is carried on, and in a long length of drain may result in an error of several inches, either above or below the required point. If the bed is solid and properly graded, the workman has then only to see that the pipes are laid in a true line and give his attention to the joints. He should lay one pipe at the outfall, and one at the head of the drain, or if it is in sections, at the point where his first manhole will come, the socket being pointed towards the head of the drain. A straight line may then be made by fixing a stout string firmly over each socket, and as each pipe is laid with its barrel resting firmly on the concrete bed, the upper part of the socket should be below and touching this line. Or a straight taut line may be fixed over the trench from top to bottom, where the centre of the pipe should come, and the centre obtained by a movable plum-bob hung on the line. The joints are then made as described earlier. When the bed is not properly formed and graded, it will be necessary to fix sight rails at their proper levels, so that the workman can, with a boring rod, get a regular gradient.

After the drain has been laid it should be covered with loose boards, to prevent any falling bricks, etc., breaking the pipes, and allowed to stand for twelve hours, to allow time for the cement in the joints to set. It should then be plugged up at its lower end and filled with water. At least a 2 ft. head should be insisted on. This will give a pressure equal to nearly 1 lb. to the square inch. If at the end of an hour the water has not fallen the drain may be said to be sound. In good pipes there should be no sweating whilst they are under this test, and it is as well to see that the pipes have not been smeared with grease to hide this defect. It should then be seen that the pipes are laid straight and uniform. On laying the straight edge on the sockets it should be firm, not ride. The fall should be checked by a straight edge and spirit level, or a clinometer. I have seen men take the fall of a drain by laying the spirit level on the barrel of the pipe. This is a mistake, as it can readily be seen that no check on the evenness of the grade can be obtained in this way. The traps must be examined to see that they are set firmly and level, and have a sufficent seal. The pipes should be looked through from end to end, or manhole to manhole, and this can be done, if the sun is shining, by your assistant holding a piece of looking glass at one end, whilst you look through from the other. If the looking glass is not obtainable, a lighted candle will answer the purpose. If the mirror or candle cannot be seen, either the drain has not been laid straight, or there is some obstruction in the pipe, and the fault must be remedied. Care should be taken to see that no ridges have been formed on the bottom of the pipes by the cement being squeezed through whilst making the joints. A small electric lamp on wheels is very useful for this purpose.

If the drain is satisfactory in all respects it may be covered up. This should be done by first filling in the sides with small loose earth and carefully ramming. Then the top of the pipes are covered with earth, free from stones, but no ramming should be done until about two feet of earth covers them. It is advisable to again test the pipes; in fact when they pass under a house it should be insisted on; as in all probability settling will take place, the surface should not be finished off until the ground is solid. If earthenware pipes are laid under a building, they should be surrounded with concrete before being filled in. The concrete should be of equal thickness all round, and not as is often the case, rounded off from the top. Arches should be turned over the pipes, when they pass under a wall, to take any pressure that might be caused by subsidence. Iron pipes are more trustworthy for constructing a drain which passes under a dwelling house. They may be laid in the way described for earthenware pipes, or if in a basement, may be carried on brick piers, or on iron brackets built into the wall. Manholes are necessary in long lengths of drain to allow of their being easily cleaned. They should also be built at any change of direction in the main drain, and at all principal points of connection, but are not absolutely necessary where only one short branch is brought into the main drain. Such a connection can be made by means of a junction, as described earlier. Manholes should be built large enough to allow a man to work in them with drain rods. The drainage system should be so arranged that no manhole is required inside a house; there is a danger of drain air escaping through the joints of the cover.

Where expense is not considered, the inner face of the manhole should be built of white glazed bricks, set in cement mortar. If this is not done the sides should be rendered in cement. The channels should be formed of specially made half pipes or concrete rendered in cement. The floor of the chamber should be sloped towards the centre channel, so that splashings may drain back into it. Channels receiving branch drains must not discharge opposite each other, as there is the danger of one discharge flowing up the other and fouling it, especially if it is from a branch drain that is used intermittently. All manholes should be fitted with air tight covers. Stone covers are unsuitable unless the manholes are at some distance from the house and away from all traffic. The joints can seldom be made air tight, and they are difficult to remove. There are several iron covers on the market, and in selecting one, two points should be borne in mind: that when fixed they will be permanently air tight and easily removed. One which appears to answer this purpose is the "Condensation" manhole cover. The frame has a channel running round it. There are two covers, the inner one being in the shape of a dome. The warm air in the drain condenses on the iron, runs down the surface into the channel, and forms a water seal. Iron drain pipes are cast with inspection eyes and covers fitting to them. They can be rendered air tight by using a felt washer and bolting them together. It is important that drains should be well ventilated, and if possible a current of air should be constantly passing through them. This will prevent any impure gases generating in the drain, and relieve any pressure caused by heavy discharges which might otherwise unsyphon the traps.

To ventilate a drain it requires two openings both open to the outer air. One is usually fixed low down on the house side of the sewer, at the lowest end of the drain, and the other taken up from the highest point. This is done by carrying an open pipe up the side of the house. A current of air is then caused by the difference of temperature between the air inside the drain and that outside. That in the drain being warmer expands and becomes lighter and rises, that outside being heavier, enters the drain at its lower opening to take the place of the displaced air, and in its turn also becoming warmer, rises, and passes through the opening at the higher point of the drain. This will go on so long as the difference of temperature in the air inside and outside the pipes continues. The action of the wind when blowing across the outlet pipe also assists this upward current. It has been proved by experiments that the best results are obtained when the outlet and inlet are not more than 150 ft. from one another, although the change takes place in a lesser degree when that distance is increased; still it is advisable, if the drain is more than 250 ft. long, to divide it into sections and ventilate each one separately. To prevent any obstruction to the free flow of air the ventilation pipe should be carried up straight throughout its entire length. If bends cannot be avoided they must be "slow" ones. The pipe should be carried up above the highest point of the roof and well away from all windows, skylights, or chimneys. The sectional area of both inlet and outlet should be equal to that of the drain. I have seen a 2 in. pipe fixed to act as a upcast shaft for a long length of 6 in. drain. It must be remembered that the areas of circles increase as the square of their diameters. The area of a 2 in. pipe is 3·141 square inches, that of a 6 in. pipe 28·274 square inches, so that it would require nine 2 in. pipes to equal the area of one 6 in.

When I left England the drains in many Urban and Rural districts were ventilated by the rain water pipes. This is a dangerous practice, for when the air in the drain, displaced by the sudden rush of water during heavy showers, is forced to the outlet, it is met by the column of water descending the pipe from the roof, and is forced out in some other direction. There is also the danger of drain air entering windows, or finding its way under the roof covering and into the house. Also the joints, which are seldom air tight, afford ready means for its escape. Iron pipes are generally used for ventilating drains, but unless galvanized, or treated by some process such as described earlier, rust collects and falls to the bottom, where it lodges until it may completely stop up the air passage. I have found many bends at the bottom of ventilating pipes choked with rust so that the pipe is rendered useless. Bends for fixing under ventilating pipes and for connecting them to the drain should have a platform cast on them, so that they may be fixed firmly. Some are provided with a pocket to receive any rust that may fall down from the pipe, but I think it better to use iron which will not rust, as the pocket sooner or later becomes filled. The material need not be so strong as for drain pipes, but for a 4 in.

pipe should weigh 10 lbs. to the lineal foot. The joints should be made with caulked lead. Lead is a good material to use for ventilating pipes, the joints can be made more reliable, and there is no rust to collect. There is the disadvantage that it is more easily damaged, especially at the lower length, but this can be overcome by surrounding it with brickwork. The pipes should be made of lead weighing 7 lbs. to the square foot. Sometimes cowls are fixed at the top of ventilation pipes. Makers claim that they assist the upward current of air, and also prevent down draughts. I would advise you to accept the first statement with caution. Experience and tests will tell you if an open pipe or one with a cowl fixed on give the best results. I have found by taking readings with an anemometer that some forms of cowls impede the flow of air. They certainly, to an extent, prevent down draughts, but they provide very convenient places for birds to build their nests in, which puts a stop to both up and down draughts.

To prevent birds building in the open pipe a wire globe should be fixed at the outlet. It is advisable to take the vent pipe up as far from a drain inlet as possible, to prevent it being fouled by any back-wash that may occur. The air inlet should not be fixed on the public footpath with an open grating; the spaces between the bars get choked with dirt, and if fixed directly over the trap, that fitting also is frequently choked. If fixed on the public footpath a dirt box should be provided, as shown in drawing. A better plan is to carry a length of pipe from a junction fixed over the disconnecting trap, up the side of the house or boundary wall, and terminate in a grating fixed flush with the brickwork. If fronting a public thoroughfare they should be fixed where they are not likely to cause a nuisance, should any back draught occur. To prevent the effects of a back draught being felt, sometimes a "mica valve" is fixed, but these are liable to get out of order, especially in this climate, and I think it much better to have the open grating. If the disconnecting trap is built in a chamber, the air inlet pipe can be taken up from the side of the chamber. I mentioned earlier that the usual way to ventilate a drain was to fix the inlet at the lower end and the outlet at the highest point of the system. If this is done you will see that the contents of the drain travel in one direction, and the air current in another.

There are a few engineers who advocate reversing the position of the inlet and outlet so that the air is flowing in the same direction as the sewage. I am not aware that this has given better results, but by adopting this system to houses fronting on to a street where the sewer is laid, you do away with the chance of any nuisance, either imaginary or real, from the inlet. Generally speaking the size of a house drain is determined by rule of thumb: a 4 in. is laid for a small house, and a 6 in. for a large sized one. In draining a block of houses in conjunction, the size of the drain should not be left to chance. Frequently a 9 in. drain is put in where a 6 in. would be ample. First we must find out the number of people living on the premises to be drained and the amount of liquid refuse to be disposed of. This is practically governed by the amount of water supplied per head, and varies in different towns, from 15 to 30 gallons per twenty-four hours. To have a drain too large for the work it has to do is a mistake, because not only does it provide more room for splashing, and consequent soiling, which during the time the drain is not working will decompose and generate foul gases, but the maximum flow through it will be much smaller.

A drain running half full is less likely to become choked than one running only a quarter full, because the deeper the water runs in a drain, the quicker is the velocity and consequently greater cleansing power. A 4 in. drain pipe holds 1·088 gallons, a 6 in. 2·448 gallons, so that a 4 in. pipe placed vertically and half full of water would equal a 6 in. scarcely a quarter full. Lay them horizontally and it will be seen that the 4 in. pipe has a good scouring flow, whilst the 6 in. with the same quantity of water in it has a much poorer one. Suppose we take 24 gallons per head per day as the amount of liquid waste to be got rid of. It must be remembered that this discharge is not equally distributed, and it is generally assumed that half of the total quantity will pass through the drain in six hours. This gives us 2 gallons per head per hour to be provided for. In addition to this we must provide for the maximum rain fall. This of course varies in different countries. We might take one inch per hour as the amount to be provided for. In Hongkong it would be much more than this, although a large proportion of the rainfall is taken into the storm water drains.

One inch of rain gives us nearly half a gallon for each square foot of surface. If we calculate for a house having 3,000 square feet of roof and yard area, and occupied by ten persons, this will give us 1,520 gallons of liquid refuse to be carried off each hour. From experiments carried out it has been found that a velocity of 3 ft. per second will carry off large shingle, and a velocity of 4 ft. per second small broken stones. The former has been accepted as the minimum velocity that should be allowed to secure a self cleansing action. This can be obtained where pipes are running full or half full by a fall of 1 in 50 for a 4 in. drain, and 1 in 70 for a 6 in. drain. But the drain is not always running half full, and we should at times get less than our minimum velocity. We must also allow for friction caused by bends and possible rough surfaces. To obtain a velocity of 3 ft. per second, when the drain is running one quarter full, the following falls must be given: 4 in. 1 in 42, 6 in. 1 in 62, 9 in. 1 in 95. When running full or half full the velocity would be 4½ ft. per second. In practice the rule is to multiply the diameter of the pipe by 10. This will give the length in feet which should have a fall of 1 foot. $4 \times 10 = 40$ ft. run for 1 ft. fall or 1 in 40; $6 \times 10 = 60$ ft. run for 1 ft. fall or 1 in 60; $9 \times 10 = 90$ ft. run for 1 ft. fall, or 1 in 90.

We now know the amount of sewage to be dealt with and the fall to give the pipes to maintain a self cleansing velocity, and by referring to any book of engineering tables, we can find the size of pipe necessary to take off this amount. A 4 in. pipe laid to a fall of 1 in 40 will discharge about 145 gallons per minute, so that a 4 in. drain is not only large enough for the house we have mentioned, but is more than capable of carrying off the liquid refuse from five such houses. Even in the case of large hotels, where it may be necessary to lay a 6 in. main drain, it will generally be found that the branches need not be more than four inches in diameter. A formula for finding the velocity of flow through pipes, and one which is easy to work out is $V = 55\sqrt{H_2F}$ (where V=velocity in feet per minute, H=hydraulic mean depth, F=fall in feet per mile). The hydraulic mean depth is the area of flow in square feet, divided by the wetted perimeter in lineal feet. The discharge is calculated by multiplying the velocity by the area of pipe in square feet: $D = V \times A$ (where D=discharge in cubic feet per minute); then $D \times 6{\cdot}23$=discharge in gallons.

If the minimum fall cannot be obtained, an automatic flushing tank should be fixed at the head of the drain, and its contents regulated to discharge at fixed intervals, governed by the length and fall of drain, the matter required to be carried away, and the capacity of the tank. There are two kinds of automatic flushing tanks, the "Tipper" and "Syphonic." The "Tipper" discharges water from a tank which works on a pivot fixed so that the centre of gravity is displaced as the quantity of water increases, until the tank falls over, discharges its contents, and returns to its first position. This pattern of tank is liable to get out of order, and seldom works satisfactorily for any length of time. The form of the "Syphonic" flushing tank will be seen from the sketch. As the tank fills from the tap, the water rises in the space between the two cylinders. The top of the inner cylinder is curved inwards, so that when the water reaches this level it enters that cylinder with sufficient force to drive the air in front of it, and the weight of the water in the tank being heavier than the air in the cylinder, rushes down it until the lower level of the outer cylinder is reached. The tank must either be left open or supplied with an air inlet, and should not discharge near to a trap. In towns where the supply of water is limited, these tanks can be supplied by the rain water, but of course there is the disadvantage that the drains only get flushed in wet weather. They are also supplied by the discharges from baths and wash basins, but this is not a good arrangement, as the interior of the tank becomes very foul, especially if the intervals of filling the tank are long ones. Mention was made during the lecture of the water test for drains. The lower end of the drain is plugged up, either by an indiarubber bag inflated with air by means of a small hand pump, or by a screw stopper.

These screw stoppers consist of two discs of galvanized iron, between which a hollow rubber ring is fixed in a groove. It is screwed up by a key which causes the rubber to expand and fit against the interior sides of the pipe. The drain is then filled with water until the level required to give the desired pressure to the pipes is reached. The objection to the water test is that the pressure is not equally divided, the pipes at the lower end being subjected to a greater pressure than those at the upper end of the drain, so that it is advisable when testing long lengths to divide it into sections. The smoke test is useful for ventilating and soil pipes, and for internal sanitary fittings. It may be applied either by a smoke machine or a rocket. The rocket is filled with a powder which on being lit gives off volumes of dense smoke. The smoke machine consists of a bellows and combustion chamber. The outer ring of the combustion chamber is filled with water, which forms a seal and prevents any of the smoke escaping. The inner chamber is filled with prepared smoke paper or cotton waste. By pumping the bellows the smoke is forced into a flexible tube which is fitted to the drain or soil pipe. The air test consists of stopping up all inlets and pumping air into the drain or soil pipe until a certain pressure is reached which is recorded on a gauge. Any fall in the gauge indicates an escape of air, and the point of escape must be discovered and the fault remedied. There are also the chemical tests, either by pouring oil of peppermint down the soil pipe followed up by a pail of hot water, or by using glass tubes containing chemicals which give off a very strong odour. They are not very reliable and I do not recommend their use. Now a few words with regard to the maintenance of drains.

Many of you, no doubt, have had experience of the carelessness with which tenants of houses treat the drains, not only here but also in England. There are plenty of people who imagine that a drain trap should be the receptacle for anything that will go down it, and proceed to sweep the dirt in the yard towards it. What wont go down is taken up and disposed of in some other way. Even when the drain refuses to be stuffed any more, in 75 per cent. of cases in Hongkong a blacksmith or painter, or in fact any man except one who understands anything about drains, is called in, who promptly knocks a hole in the bottom of the trap, and if that does not answer, one or two in the pipe where the stoppage is, lets the sewage soak away into the surrounding soil, covers up the evidence of his skill, says "can do" and sends in his bill.

A certain amount of solids are bound to lodge in a yard trap, but if these were to be removed by hand once or twice a week, stoppage of the house drains would be less frequent. Manhole covers are frequently luted off and the manholes converted into receptacles for house refuse. I have frequently found the grating over the disconnecting trap, which has been fitted to allow fresh air to gain access to the drain, closed up with a piece of tin plate fastened to the under side of the grating. The tenant will complain that a very bad smell proceeds from the trap, and that the grating has been closed to prevent it being noticed; but you will often find, if you investigate into the cause, that night soil is emptied down the yard trap, or that a urinal, without any provision being made for flushing it, has been erected and allowed to discharge into the house drain. I have also come across vent pipes, the tops of which have had a piece of wood inserted in them for the purpose of supporting one end of a bamboo. This makes a very convenient clothes line, but does not assist in the ventilation of the drain. If a drain becomes choked it requires cleansing in an intelligent manner. The section in which the stoppage occurs should be found, and the manholes above and below it opened. The obstruction can then be easily removed with the aid of drain rods. If the drains have been designed and laid properly it is very seldom that it will be found necessary to break a pipe to remove an obstruction. If this has to be done, see that a new pipe is put in its place. Never allow the workman to make the hole good with a piece of tile and mortar as is very often done.

In conclusion let us go through the particular points to which attention must be paid in carrying out drainage works. See that the pipes used are perfectly smooth inside, true in section and free from cracks. Lay all pipes on a solid bed, and in a straight line throughout its entire length, or from manhole to manhole. Build manholes at each change of direction, and at junction with principal branch drains. Keep all drains outside the building if possible. If this cannot be done the pipes which pass under the building should be of iron. No drain inlet, manhole, or vent pipe to be inside a house. All traps to be of a self cleansing pattern, and to have an adequate water seal. No drain should be larger than actually necessary for the work it has to do. The minimum fall for a 4 in. drain to be 1 in. 40, and for a 6 in. 1 in 60. The main drain should be disconnected from the sewer and provided with an air inlet and outlet. When finished the whole of the work should be tested, and be able to stand a greater pressure than it would be likely to receive in practice. It is advisable that a ground plan of the house, showing the position of the drains, should be prepared and kept for future reference.

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WATER SUPPLY

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NO time need be wasted in dealing with the necessity for a good water supply, it will be taken for granted; and by way of preface there will be given a few memoranda about water which are the groundwork of every waterworks engineer's practice. A gallon of water weighs 10 lbs. A cubic foot of water is $6\frac{1}{4}$ gallons. A ton of water contains 36 cubic feet or 224 gallons. An acre of water one inch deep amounts to 3,630 cubic feet or 101 tons. Water is practically incompressible. The freezing point of water is 32° Fahr. The pressure exerted by still water is 43 lbs. per square inch for every 100 feet head.

The subject will, as far as possible, be treated under the following heads, but in many cases the questions discussed overlap, and it is impossible to keep an exact division:

(1) Quality of water required.

(2) Quantity of water required.

(3) Sources of supply—rainfall, wells, rivers and springs, reservoirs, evaporation of sea water, gravitation and pumping.

(4) Filtration.

(5) Distribution—mains, service reservoirs, house fittings, meters.

QUALITY OF WATER REQUIRED.

The quality of the water to be supplied to a town is a subject passing beyond the bounds of engineering into chemistry and bacteriology; but it is necessary that the engineer should know enough about the matter himself to enable him to form at least a preliminary judgment on the sources of supply, and to enable him to form an opinion as to the probable efficiency of such filtration works as he may deem it necessary to construct.

Absolutely pure water is not to be found in practice; it is always subject to contamination under one of the following heads:

(1) Matter in suspension.

(2) Mineral matter in solution

(3) Organic matter.

Matter in suspension—the sand, soil, dust and vegetable matter brought down to the rivers and reservoirs with the rain—is easily seem, and in general easily dealt with by settlement and filtration. Except in the case of deep well water, and of water from large reservoirs where flood water is excluded, filtration through 2 or 3 feet of fine sand is the recognized practice in England, and even in the United States—which country, although priding itself on its progress, is far behind the times in most questions affecting the safety of human life—filtration, though on a different system, is becoming general.

Of mineral matter in solution the most common is lime; it is this which causes the hardness of water. To a moderate degree it is of no disadvantage for drinking purposes; but for washing and manufacturing purposes soft water possesses unquestionable recommendations.

In passing through chalk and limestone formations rainwater takes up lime to a greater or less degree: the water from chalk wells sometimes contains 30 to 50 grains of lime salts per gallon. The grains of lime salts contained in a gallon of water are generally taken as the standard of hardness—one grain per gallon constituting what is termed one degree of hardness. Fortunately there is a simple process for reducing the hardness of water on a large scale. Pure water will only dissolve limestone to a very slight extent, but it is by means of the carbonic acid, which all water contains, that hardness is produced. If therefore this carbonic acid can be driven away the superfluous carbonate of lime is precipitated and the water softened. The remedy is a curious one. To get rid of the lime in water more lime must be added; the lime combines with the excess of carbonic acid to form the almost insoluble carbonate of lime which is then precipitated along with the original carbonate of lime. In this process, when first adopted, time had to be allowed for the precipitate to settle in large tanks, but it has been much cheapened in late years by the adoption of filter presses for the removal of the carbonate of lime; and is now in use in several large supplies in England—Southampton, Canterbury, Wellingboro, and Stroud among others, the hardness being reduced to about 5 degrees which is found not inconvenient for use. Besides this hardness due to carbonate of lime, which is usually called temporary hardness, there is in many waters a hardness due to sulphate of lime, and this is called permanent hardness; it occurs fortunately to a much less extent than temporary hardness.

By far the most important source of contamination of a water supply is by organic matter. It is now well known that almost all water in its natural state, except that from deep wells, contains thousands of minute organisms known as bacteria; some of these are perfectly harmless, but some are believed to be the direct causes of such diseases as typhoid and cholera. A chemical examination will show in what degree a water has been contaminated with animal and vegetable substances, and by this means one may infer the probability or otherwise of the presence of harmful bacteria; but by the microscopic examination of water it is found that not only can one count the number of bactaria in a sample of water, but one can recognize the harmful from the harmless species.

It is now well known that large storage reservoirs not only help in the removal of suspended solids and mineral matter in solution, but also effect a very considerable bacterial improvement, and it has been found that ordinary sand filtration, which up to 20 years ago was thought only capable of removing the suspended impurities from water, removes also 98 per cent. of the bacteria present. It has also been found that the best results are obtained where water is stored for the longest period and filtered at the slowest rate through the greatest depth of sand. This does not free the engineer from the responsibility of choosing, so far as can be, sources of supply free from contamination. Nothing better than uncultivated hills free from houses, such as the Tytam drainage area can be expected; deep wells may generally be trusted. Rivers have been found to be to a large extent self purifying—that is to say, a sufficient number of miles below the source of contamination the water will be found to have materially improved in quality; but there are few rivers which are not throughout their course so continuously liable to contamination as to render filtration a necessity.

Some stir has been made in the papers recently about the increasing difficulty at home in finding sources of supply free from danger of pollution; but a short enquiry into the matter shows that it is, like most questions in engineering, merely a matter of cost. In England and Wales there are 3,000 square miles or nearly 2,000,000 acres of wholly uninhabited uplands suitable for the collection of water. All this land is in districts of heavy rainfall, where the average is perhaps 50 to 60 inches a year; with suitable works there is little doubt but that 30 inches could be collected. Now it has already been stated that an acre of water an inch deep amounts to 3,630 cubic feet, or about 22,000 gallons, and the 2,000,000 acres would therefore produce 1,320,000 million gallons in a year. Now if we divide this by 365 for the days in the year, and by 20 for the number of gallons required per head, you will find this area of 3,000 square miles would give sufficient water for 180,000,000 people. The population of England and Wales amounts to 32,000,000 so that it appears the old country has room to grow yet without great fear for its water supply.

QUANTITY REQUIRED.

The consumption of water in a town varies according to the occupations of its inhabitants, the nature of the industries carried on, and the habits of the people. In England 20 to 25 gallons per head per day is considered ample for all purposes, unless there are special conditions such as manufactures requiring large quantities of water. In a few towns in England the meter system has been adopted, and the consumption thereby reduced below 20 gallons per head. This result has also in many cases been obtained by strict attention to fittings and mains without the help of house meters. In London the consumption for all purposes amounts to 33 gallons; and in Berlin, a metered town, it is 17 gallons per head per day. In Leicester, an unmetered town, the domestic consumption is 12 gallons per head per day. In North America water appears to be used lavishly, and the consumption in the large cities varies from 70 to 150 gallons per head per day. In a recent journey across the States, by way of New York and Chicago, I failed to see any extra cleanliness to justify this large consumption of water, and cannot but think that the greater part of it is pure waste; it is probably the result of having practically inexhaustible sources of supply, and water consequently cheap.

It must not be overlooked that there are two distinct forms of waste: the consumers waste through defective fittings, taps left running, and lavish use of water, and the suppliers waste through defective mains. Both of these have to be guarded against by the engineer, and the probability that neither can be entirely eliminated has to be considered in his estimate of the quantity of water required. There is a further differentiation to be made between waste and extravagance. Coolies may sometimes be seen watering the concrete surfacing round a house on a hot day, apparently with the idea of keeping the house cool, this may be classed as extravagance. It probably is of some slight use for the purpose of coolness and it certainly produces a pleasant cool appearance. When water is abundant, and the consumer is prepared to pay for it, there can be no objection to such extravagance; but in times of scarcity it is inadmissible, no matter how well the consumer may be able to pay for it. In Hongkong the sources of supply are limited, and works necessarily expensive; this is owing to the nature of the country. The Tytam dam, 120 feet high, holds 400,000,000 gallons; on the new Birmingham Waterworks a similar dam holds 7,000,000,000 gallons. We cannot expect, therefore, except at great cost, to obtain the supply given in more favourably situated places.

One must always allow for local conditions; the requirements in England are very different to those in Hongkong. I am in the habit, in Hongkong, of allowing 20 gallons per head per day for Europeans. A bucket holds from 3 to 5 gallons, a "Shanghai tub" 4 inches deep about 6 gallons, and personally I find I can get a very comfortable bath out of this amount. In European houses a large amount of water is wasted in what the servants consider washing, *i.e.*, sluicing buckets full of water over a floor. A little more brush work and much less water would produce far more cleanliness. Among the coolie classes who have per head a less floor area to wash than Europeans, and who do not indulge in our baths, I consider 10 gallons per head per day should be sufficient, this happy result, however, can at present only be obtained where a check is put on the coolies' waste by obliging him to carry the water from a street tap—not an ideal system by any means, as by a very small expenditure in piping, gravity will do the carrying for him, but, as Chinese human nature goes, the cheapest method of reducing waste. This waste is mainly the result of leaky taps and taps carelessly left running. A hole in a pipe one-eighth inch diameter, under a head of water of 104 feet, will discharge nearly 4,000 gallons per day, so it may easily be understood that a very small leak unattended to will soon waste a very large amount of water.

Having then settled the number of gallons to be supplied per head, it is a simple matter to multiply that figure into the population and thus obtain the total quantity required; but when this is done we have to consider what provision should be made for future increase of the population. It is the practice of many waterworks engineers to take the census returns over a series of years and from them determine the rate of increase of population. In a long settled district in the old country this is a fairly satisfactory method, but in a place like Hongkong where the increase in population is mainly the result of immigration and not the result of the excess of births over deaths, it is useless, and the best that can be done is to provide an ample margin over present requirements, and to lay out the works so that they may be extended as necessary without interrupting the supply.

Kowloon has provided an instance of rapid increase. In 1891 Mr. Cooper, then Director of Public Works, reported on the supply of the Peninsula. He estimated the present requirements at 147,000 gallons a day, and on his recommendation works were carried out which supplied 230,000 gallons a day. The land and boat population in 1891 was 26,500, and showed an increase in the ten years since 1881 of 96 per cent. Mr. Cooper thought it scarcely probable that this rate of increase could be maintained; the facts however have entirely eclipsed the probabilities. At the interin census of 1897 the population amounted to 36,000, and on this basis I estimated in a Report to the Government in 1900 that the population then requiring a supply amounted to 44,000. When, however, the census returns of 1901 were published, it was found that the pupulation of the district to be supplied amounted to 66,000, an increase of 150 per cent. in 10 years. The works now in hand will supply twice the present population. It has been said that a supply of ten times the present requirements should be provided; this appears to me entravagant, as it would only lead to waste of much money in interest between the time the works were carried out and the time they were used to their full capacity. It is one of those questions in which each case must be judged on its merits. There are country districts in England for which it would be folly to provide for more than 20 per cent. beyond present requirements; and again there are cases—the Tytam dam is one—where it is false economy to leave a work incomplete on the supposition that its completion will not be required for some years to come, the small amount of interest thus saved being more than swallowed up in the extra cost of carrying out the work in two jobs instead of in one.

It must always be born in mind that waterworks take time to construct, and often as long to discuss before construction is commenced, and these are further factors showing the necessity of ample provision beyond present requirements in all places where an immediate increase of the population is probable.

SOURCES OF SUPPLY.

Rainfall.—All waterworks are ultimately dependent upon the rain for their supply of water, whether taken from storage reservoirs, from rivers, springs, or from the deepest wells. No matter what water we get it has at one time fallen upon the surface of the earth in the form of rain, and consequently a knowledge of rainfall, and of the proper interpretation to be put upon rainfall statistics, forms an important branch of waterworks engineering.

The only means of obtaining an accurate knowledge of the rainfall of a place is by the use of a rain gauge. This consists of a circular metallic funnel for catching the rain and a jug or mug below for storing it. It is usual to measure the rain daily, and this is done by pouring it into a graduated glass cylinder. This glass cylinder is made of a considerably smaller diameter than the rim of the funnel, so that an inch of rain falling on the funnel will measure considerably more than an inch in the glass, and the glass is graduated accordingly. By this means the depth of rain is exaggerated so that the amount may be read with ease to one-hundredth of an inch. Self-recording gauges are also used by which we are enabled to tell the amount of rain falling in a few minutes; but the yearly rainfall is the quantity of most importance to a waterworks engineer.

It may be as well to give some idea of the variation of rainfall over the world. It is doubtful if there are any parts of the world absolutely rainless, but there are many places which, so far as water supply is concerned, are practically so. In Egypt the average rainfall at Alexandria is 8 inches a year, and at Cairo 1½ inches, and following the course of the Nile above Cairo for several hundred miles the yearly fall is still less than this. Sunshine is one of the features of Egypt, and this small rainfall is consequently quickly evaporated and the country is left entirely dependent on the Nile for its water supply, and so it happens that for waterworks purposes Egypt may be considered rainless, and a knowledge of the rainfall of central Africa, at the sources of the Nile, is of more use than a knowledge of the rainfall of Egypt itself. The highest known yearly rainfall is on the Khasi Hills in Assam and amounts on an average of 20 years to 500 inches. In Hongkong the yearly rainfall amounts to 85 inches. In England it varies from 20 inches in Norfolk to 170 at The Stye in the Lake District.

There is some relationship between the rainfall and the height and configuration of the land. Generally the rainfall increases with the altitude, and generally there is more rain on the side of a hill from whence the rain comes than on the lee side; but this relationship is variable and uncertain, so that, though in many cases having no rain gauge, we are obliged to draw conclusions which may be considerably wide of the mark, we should always fix a rain gauge where exact knowledge of the amount of rainfall is of any importance.

In Fig. 1 an instance is given of this uncertainty in the relationship between rainfall and the configuration of the land. At each of the points A, B, C, D, &c., a rain gauge was fixed, and the result of the measurements by these gauges is shown by the dotted line. If the rainfall were simply a question of altitude one would expect a gradual increase from C to N; but this was not found to be the case, the rainfall at C being found to be 20 per cent. more than at D, and 30 per cent. more than at J, and its uncertainty being shown by the irregularity of the dotted line. At the Public Gardens in Hongkong the average rainfall is 1 per cent. above the Observatory; at Tytam 13 per cent., and at Victoria Peak 14 per cent. above the Observatory. Some simple relationships have been established in connection with annual rainfall which are of great use to an engineer. It has been found that the wettest year has, in England, about half as much rain again as the mean; that the driest year has about one-third less than the mean; that the average of the two driest consecutive years is one-quarter less than the mean; and that the average of the three driest consecutive years is one-fifth less than the mean.

The rate at which rain falls has to be considered in designing overflows and catchwaters. In Hongkong in the great storm of 1889, we had 3 inches an hour for four consecutive hours and, with the small areas, almost impervious ground, and steep hills we have to deal with here, no works are safe unless designed to carry at least this amount. Rain often falls much more quickly than this for a short period, and in London half an inch has been recorded in five minutes; but such falls are very local and of short duration, and consequently the maximum flood in a large river will be at a much lower rate. If, for instance, we have an area of 1,000 acres and it is raining at the rate of 3 inches an hour over 100 acres and not raining at all on the other 900 acres, the resulting flood in the channel draining the whole area will be at the rate ·30 inch rain per hour.

WELLS.—In porous strata, especially in chalk and sandstone, a large proportion of the rain which falls on the surface quickly disappears. This water may be stored in the pores of the rock, and in fissures which are common in chalk formations, or, as more generally happens, it may flow slowly through the rock and again find its way to the surface in the form of springs. The water from shallow wells is generally liable to organic pollution and should always be looked upon with suspicion; but the water from deep wells having filtered through several hundred feet of rock is generally free from any but mineral contamination.

There are two distinct kinds of wells: a well proper 6 to 10 feet diameter, generally excavated by hand and lined, where not through rock, with brickwork, and a borehole 6 to 12 inches diameter, made by machinery and lined where necessary with iron tubes. The term "Artesian Well" is often applied to boreholes generally, and sometimes only to overflowing ones; it is however a name which might very well be done without. It is of little importance to an engineer to know whether a well is overflowing or not unless he can know to what height it will overflow.

In considering a scheme for water supply from wells, some knowledge of geology is essential. It is useless to sink a well into impervious strata such as clay, or into granite, unless there is a prospect of finding water-bearing strata below. In passing through the pores of rock, the water requires a fall or head to produce a flow, just as in a river or drain; and so it happens that when pumping is first commenced in a well, the water level quickly drops and what is called a cone of depression is formed. The water flowing in from all sides, the depth of water in the well will adjust itself to the quantity pumped, the area of the cone of depression will extend for some distance round the well, so that pumping from one well, is always liable to reduce the yield of a neighbouring well. In order to increase the yield of a well it is customary to drive tunnels from the bottom of the well thus extending the cone of depression and consequent supply; this cannot be done with boreholes.

It must not be imagined that there is an unlimited supply to be obtained if only wells are sunk deep enough. As has been already said whatever water we get comes originally from the rainfall which gets into the strata at its exposed surfaces, and the yield of a well must depend on the amount of rain, the capacity of the strata for absorbing it, and the capacity of the well to drain the water charged strata. Nor is there any rule by which the yield of a well can be determined beforehand; it must be a matter of experience and largely dependent on a knowledge of the geology of the neighbourhood.

Rivers and Springs.—Rivers are much more liable to pollution than wells or springs, as in all settled countries they take the drainage from towns and villages in their course. There are rivers which are little better than open sewers, and these must of course be avoided as sources of supply; and there are again rivers such as the Woosung at Shanghai which a waterworks engineer would not select if he had any choice, but which he is sometimes obliged to make the best of; but generally a river forms a cheap and satisfactory source of supply. The London water companies take 100,000,000 gallons a day, or half the supply of the metropolis, from the Thames, and a still larger quantity will be taken when the Staines reservoirs are completed. Before works are designed for utilizing the water from a river, it is necessary to know the amount of water which can be depended on in dry weather, and for this purpose gaugings must be made of its flow. In a large river this can only be done by taking cross sections of the channel in as straight a reach as is available and measuring the velocity by a current meter, or by floats; in smaller streams a weir may be built across the channel and the discharge determined by measurements of the height of water over its crest. The works for supplying water from a river are generally similar to those from any other source; in most cases a pumping engine will be required and filter beds which will be dealt with later on. There are cases in which the water of a river may be taken not out of the river itself, but out of the saturated beds of gravel or alluvial soil through which the river runs. For this purpose shallow wells are sunk in the neighbourhood of the river, and tunnels driven in a horizontal direction to tap the water in the soil; in this way a plentiful supply of water may be obtained of a better quality than if taken direct from the river, having undergone a process of natural filtration. The town of Derby is supplied in this way, and a scheme for tapping the under-ground waters of the Nile is about to be carried out to increase the supply of Cairo.

Reservoirs.—The greater part of the rain which falls on the earth passes away in floods, and consequently is not available for supply from wells or from rivers. The supply obtainable from a river being limited to the quantity which may be taken in a dry season, it thus happens that in a thickly populated country most of the large towns are supplied with water from reservoirs. The town of Birmingham after being supplied for years from wells has now nearly completed a large scheme to supply 27,000,000 gallons a day from reservoirs in Mid. Wales; Liverpool obtains its supply from Lake Vyrnwy in Wales; Manchester, supplied till recently from reservoirs built 50 years ago in Longendale, has within the past few years brought in an increased supply from Lake Thirlmere; Glasgow obtains its water form Loch Katrine—and lakes are merely natural reservoirs. Most reservoirs are formed by the construction of an earth or masonry dam across a valley; the most suitable sites are those which combine a narrow gorge across which the dam may be built with a widening out of the valley above the gorge to give a large area for impounding water.

Having selected a suitable site the first question to be settled is the height of the dam, and this is generally governed by the size of the catchment area, as it is obvious it would be useless to have a reservoir so large that it never filled, or so small that it overflowed at every shower. Owing to the great fluctuations in rainfall it is only in exceptional cases, where collecting grounds are very limited, that it is advisable to build a reservoir of such a size that no water shall run to waste. The Tytam reservoir, for instance, would have to be at least twice its present capacity if it were to hold such a rainfall as that of May, 1889, when 48 inches fell during the month, and the water thus collected being spread over many years would make but a small addition to the annual supply. It is cheaper in most cases to build two smaller reservoirs partially utilizing separate collecting grounds than to build one large reservoir utilizing the whole of the water from one of these areas.

Before we can decide what proportion of the rainfall our reservoir should be made to impound, we must find out what proportion is available for impounding. In a hilly country like Hongkong there is little doubt but that all the rain falling in heavy continuous storms quickly finds its way into the streams; but on grounds well covered with long grass and shrubs, comparatively heavy showers may fall, and if succeeded by bright intervals the whole of the rain will be evaporated and there will be no flow off the ground. Experiments have been made in England with small patches of ground to ascertain the amount of evaporation, and it has been found that in the Thames basin, out of a rainfall of 27½ inches a year, as much as 18 inches is accounted for by evaporation, leaving only 9½ inches for the supply of wells, springs, rivers and reservoirs. It is doubtful however if much use can be made of such experiments by the waterworks engineer. In the Tytam catchment area, for instance, it would be exceedingly difficult to select an average sample of ground: some is bare rock or decomposed granite, some covered with grass and some with shrubs; and then the different slopes of the ground must be allowed for, so that nothing short of an experiment with the whole catchment area would yield decisive results. The records kept at every impounding reservoir should constitute such an experiment. A contoured survey of the reservoir will tell us its contents at every foot in depth, daily records should be kept of the height of the water and of the rainfall, and with a knowledge of the number of acres in the collecting ground we can then easily ascertain what proportion of the rainfall has found its way to the reservoir. An experiment such as this brings out the net results, as it makes allowance for evaporation from the land and absorbtion—whatever that may mean—and evaporation from the water surface in the reservoir, and leakage—all very uncertain quantities. In this way it was found that from May to August, 1895, 57 per cent. of a rainfall of 36 inches was collected at Tytam. The percentage will vary from month to month with the way in which the rainfall varies, sometimes light showers and sometimes continuous storms, and very elaborate statistics very carefully worked out are necessary for one to be able to say the exact size of reservoir required for a given catchment area, or the exact number of people that such a catchment area will supply. Fortunately any great exactitude in the matter is seldom needed. When it is an open question whether the works should provide 20 or 200 per cent. beyond present requirements, a question of 10 or 20 per cent. in the amount of rainfall which can be collected is a small matter.

In Hongkong, for the supply of 1,000,000 gallons a day, a catchment area of about a square mile is needed and a storage of about 200,000,000 gallons, but this is no absolute rule. When the year's rainfall is concentrated into three or four months a greater ratio of storage to catchment area would be desirable and, on the contrary, in an excessively dry year the catchment might with advantage be increased in proportion to the storage.

Having settled the size of the reservoir and, consequently, the height of the dam, it is necessary to decide whether the dam is to be of masonry or earth. This depends mainly on the height of the dam, on the nature of the ground on which it is to be built, and on the building material available in the neighbourhood. An earthen dam is in almost all places the cheapest form of construction; up to 60 feet high it is quite safe if properly built. Many dams have been built to a greater height, some indeed up to 100 feet; but such high dams need great care in construction and design, and in such cases a masonry dam is generally considered preferable. As an example of an earthen dam, a section is given in Fig. 3 of the dam forming the new Staines Reservoir near Windsor. Dams are usually built across the valley of a river or stream, the natural hillsides forming the reservoir bank for all but a short distance; but this is an exception to the rule, the reservoir being enclosed by artificial banks on all sides. To prevent the water escaping from the reservoir a trench is first sunk in the ground on the site of the embankment, and this trench must be sunk till impervious ground is reached—in this case to what is known to geologists as the London clay. This trench is then filled up with puddled clay or cement concrete, and a continuous wall of puddled clay is carried up to the highest water level in the reservoir; the inner slopes of the embankment are made flatter than the outer slopes, as being constantly saturated with water they are more liable to slip. About the water level they must be protected with pitching or paving to prevent the bank being washed away by the waves. The most difficult point in building an earthen dam is the question of providing, during construction, for the flow in the river or steam over which it crosses, and on this point masonry dams have a great advantage, as with good masonry or cement concrete, flood water will flow over the top without doing damage. With an earthen dam the overflow must be constructed in solid ground at one end of the embankment, and it is usual to place the outlet culvert also in solid ground by means of tunnelling. A shaft is usually built in connection with the tunnel in which are placed the outlet valves of the reservoir. Masonry dams require a foundation of sound rock, and of course it is desirable that they should be located where good building stone is abundant, otherwise the cost will be excessive. As an example of a masonry dam a section of the dam which is now being built for the water supply of Kowloon is given in Fig. 3, it will be 107 feet high from the top to the lowest part of the foundation, and about 65 feet wide at the bottom.

An ordinary masonry dam depends for stability on its weight, and consequently every precaution must be taken that it shall be as solid as possible, and also that there shall be no upward pressure of water which may tend to counteract its weight, and for this purpose it is usual to construct drains to carry away any water that may find its way through any crevice in the rock to the underside of the masonry of the dam. The overflow may be carried over the dam top; in the Kowloon dam, however, this will not be done as an equally convenient site for an everflow was found away from the main dam. The outlet is carried in a masonry culvert through the dam, the draw off pipes being arranged at different levels, so that the clearest water is always taken.

The Americans are building a masonry dam for the New York water supply 260 feet from foundation to top; when finished it will be the highest masonry dam in existance. The Assuan dam on the Nile, though it could not strictly be called a waterworks dam, is one of the largest, though not highest, works of this class. It is 130 feet high (about the height of the Tytam dam), a mile and a quarter long (about 12 times the length of Tytam), and holds 230,000,000,000 gallons (about 500 times the capacity of Tytam).

The stability of a masonry dam depends more than most things on honest conscientious work in construction. As has been already said it depends for stability on its weight. Now granite weighs 160 to 170 lbs. per cubic foot, and the whole mass of the dam will press downwards with a force equal to its bulk multiplied by this weight; but if through bad workmanship an open joint is left on the face, the water finding its way into that joint will press equally both upwards and downwards, and so will tend to relieve that part of the dam above the joint of a large part of its weight and consequent stability.

Evaporation of Sea Water.—This question has been introduced as it has occasionally been proposed as an emergency measure in a Hongkong water famine. The evaporation of sea water for drinking purposes is perfectly practicable, and is often carried out on steamships, but the cost per 1,000 gallons is so high that it is only in almost rainless places that it can compete with water obtained from ordinary sources. A pound of coal will evaporate under the most favourable circumstances 10 lbs. of water; so a ton of coal will evaporate 22,400 lbs. of water, or 2,240 gallons; so that with coal of say $7 a ton, water would cost about $3 per 1,000 gallons to evaporate. Now to compare this with an ordinary waterworks scheme, I will take the works now being carried out for the supply of Kowloon; these will supply 1,500,000 gallons a day and will cost for reservoir catchwaters and filter beds about $600,000. To pay 5 per cent. on this sum a revenue of $30,000 will be required, and this can be obtained by charging only 6 cents per 1,000 gallons for the water.

Gravitation and Pumping.—The question whether a gravitation supply is better than a pumped supply is usually a question of cost, and in estimating the cost it is necessary to take into account the working expenses, which of course are much higher in the case of a pumped supply than in the case of a gravitation supply. As an example of the way this is done I will give the comparison made between the present Kowloon pumped supply and the original gravitation scheme; the scheme which now is being carried out is a larger one and compares still more favourably with pumping.

Existing works:—	
Supply	232,000 gallons a day.
Original cost	$128,000
Capitalized cost of maintenance ($6,000 a year at 5 per cent.)	$120,000
Cost of supply per million gallons per day $\frac{248,000}{\cdot 23}$	$1,070,000
Proposed gravitation scheme:—	
Supply	590,000 gallons a day
Cost of existing works to be utilized	$ 90,000
Estimated cost of new works	$380,000
Estimated cost of maintenance (capitalized) $2,000 at 5 per cent.	$ 40,000
Cost of supply per million gallons per day $\frac{510,000}{\cdot 59}$	$860,000

There are many different forms of pumping engines, but no attempt can be made to describe them in a lecture of this sort; some reference may however be made to hydraulic motors as they are of great service in Hongkong. The water here is delivered from Tytam and Pokfulam at levels of about 400 ft. and 500 ft. above the sea; there are many houses above the 500 feet contour, though the greater part of the supply is used within 100 ft. of sea level. If the service reservoirs had been connected directly with the lower levels of the city the pressure in the mains and services there would have been excessive, and would have led to excessive leakage and waste. It was proposed to obviate this by introducing reducing valves in different places; these are valves which will reduce the pressure of the water passing through, but do no useful work. Mr. Chadwick, however, proposed that hydraulic motors should be used, and they were consequently adopted. The water passing through these motors from the higher to the lower level actuates a plunger which forces part of the supply to any required height. In this way a large part of the Peak supply is pumped and the cost of coal for a steam pump saved.

FILTRATION.

Under the heading "Quality of Water Required" the need for filtration has been pointed out, and it now remains to discuss the practical methods by which filtration is usually carried out. The usual method of filtration is, as already mentioned, to pass the water through two or three feet of fine sand; this filtration should not be hurried; and to this end the filter beds should be of ample area—the usual rule is to allow one square yard of filter to each 700 gallons per day to be filtered. In the process of filtration the upper part of the sand bed becomes choked with the suspended matter in the water, and eventually the water, owing to this choking, rises to such a height that it is necessary to shut it off and remove the upper layer of sand. On this account an additional area of filter bed has to be provided, and the size of the beds must be limited, so that too large a proportion is not put out of use at one time for cleaning. The filter bed is simply a shallow tank 6 or 8 feet deep, having drains with open joints in the bottom. Above these drains are laid the layers of filtering material: first broken stone, then coarse sand, and lastly about two or three feet of fine sand. The water is let in above the sand, and after passing through the sand comes out purified from the bottom of the bed. Fig. 4 shows a section of the Albany Filter Beds of the Hongkong Water Works. There are other means of purifying water than by ordinary sand filtration. It was discovered some years ago that contact with iron caused a considerable reduction of the organic impurities in water, but the difficulty was how to apply it. After some experimenting the most economic way was found to be to pass the water through a large iron cylinder which was kept continuously revolving; on the sides of this cylinder little shelves were formed which, as the cylinder revolved, scooped up iron filings or borings which had been previously introduced, and dropped them as they reached the top of the cylinder. This process has been found of service with some tropical waters which were so highly charged with organic matter as to be unfilterable by ordinary means. It has also been found that such waters (Singapore is one) require a much greater filtering area than ordinary waters, and that they are also much improved by aeration. In America filter beds are used of a comparatively small area, a coagulant such as sulphate of alumina being used to assist the purification, and the filter bed cleaned at short intervals by mechanical means.

DISTRIBUTION.

Mains.—Having obtained our water supply and filtered it, the next part of our business is to lead it to the houses where it is to be consumed.

First we will consider the necessary size of the mains for so doing. The quantity of water which a pipe can carry depends not only on the size of the pipe, but on the gradient to which it is laid. A 12″ pipe at a gradient of 1 in 100 will discharge about 2,000,000 gallons a day; at 1 in 200 about 1,500,000 gallons a day. But it is seldom practicable to lay a water main at an even gradient; it has to be carried up and down to suit the gradient of the roads. It has been found however that the "fall" on which the discharge depends is not the fall of the pipe itself, but the difference in level of the water surface between the intake and the place where the water discharges.

It is not sufficient however to provide a main to carry merely the daily supply at its average rate of flow. Fig. 5 shows that the maximum hourly consumption is 50 per cent. above the mean hourly consumption, so that if you have a mean consumption of say 1,000,000 gallons a day you must provide pipes capable of delivering at least 1,500,000 gallons a day. It will be shown later how in some cases the provision of this extra size of main may be avoided by means of service reservoirs; but there will always be the smaller mains beyond any service reservoir, which must be made large enough to take the maximum flow.

Cast iron pipes are most commonly used for water mains; steel pipes have been used in many places, especially where large sizes were required. They may be made, for the same strength, much lighter than cast iron pipes, and consequently where cost of carriage is a large item it is economical to use them; but so far as is known at present they cannot be expected to last so long as cast iron pipes. Most water pipes are made with what are termed spigot and socket joints. To make the joint the spigot of one pipe is forced into the socket of the next one, a piece of tarred hemp rope is caulked into the joint, a ring of plastic clay is worked round the open socket, leaving only a small hole at the top into which molten lead is poured. This fills up the space between the spigot and socket, the tarred rope preventing it finding its way into the pipes. When the lead has hardened, the clay is removed, and the lead caulked up tight with a caulking tool. There is another method of jointing cast iron pipes: by turning in a lathe the spigot of one pipe to fit exactly into the turned socket of its neighbour.

Cast iron pipes are usually coated with what is called Dr. Angus Smith's Patent Composition. This is a coal tar product, and when properly put on it not only adds considerably to the life of the pipe, but also by providing a smooth surface for the water increases its carrying capacity. The coating is applied by dipping the pipes while hot in a bath of the composition, and this must be done before any rusting has taken place. In countries liable to frost, mains must be laid with at least three feet cover and should never have less than two feet. Valves should be placed at all branches, so that if it is necessary to shut off a length of pipe to make a house connection or repair a breakage, it may be done without shutting off any large area of the district. The valves used for this purpose are called sluice valves and consist of a cast iron door, usually with gun metal faces sliding up and down between gun metal cheeks, fitted to a recess in the valve case; the valve is worked by a gun metal screw, and care must always be taken not to open or shut it too quickly, as doing so produces a severe shock in the pipes.

There is always a certain amount of air in water, and where pipes are laid up hill and down the air accumulates at the summits, and if not dealt with seriously interrupts the flow; in built districts the service pipes carry away the air, but where there is a long length of main without houses, air valves must be introduced. The usual form of air valve consists of a small chamber on the top of the pipe; a hole in the top of the chamber allows of the escape of air. The water is prevented from escaping by a rubber ball which floats in the water and is pressed against the top of the chamber when air is absent; but as soon as air accumulates in the chamber, the rubber ball drops down with the water and thus allows the air to escape. Fire hydrants are among the usual fittings of a water works; the common form is made on the same principal as an air valve. When the hose has been attached and it is wished to turn on the water, the rubber ball is forced down by a screwed spindle working in the hydrant stand pipe; on turning the spindle the other way the pressure of the water forces the ball again into the opening and so shuts off the water.

SERVICE RESERVOIRS.—Service reservoirs are required for two purposes. First as a reserve in case of break down of engines or mains, and secondly to equalize the supply and thus allow of a constant rate of filtration, and a constant flow through the supply pipes. The size of reservoir required for the latter purpose is a matter of calculation; for the former purpose a matter of judgment. The service reservoir should be placed near the middle of the district of supply, or at the end farthest from the source of supply, as in such a position its equalizing effects may be taken advantage of for reducing the size of the mains throughout the district; or it is a great advantage to have more than one service reservoir reducing to a minimum the trouble caused by a burst main; but this principle must not be carried too far, as it is much cheaper to build one large tank than a lot of small ones holding the same quantity. This is easily demonstrated: if we have two boxes, each one foot cube, they will hold between them 2 cubic feet, and their sides and ends will require 12 square feet of material; but if the two be put together, they will have the same capacity but two ends may be saved and they will require only 10 square feet of material. Some places, such as Shanghai, having no high ground near, have to get along without any service reservoir to speak of, the small tank on the water tower there holding only 150,000 gallons.

It is the general practice to cover in a service reservoir; this prevents any growth which might take place in a shallow tank, and is also a safeguard against pollution of the water. As regards the level at which a service reservoir should be built, it must depend upon circumstances. In a place like Hongkong, where the houses run from sea level to 1,800 feet above it, it is necessary to divide the supply into zones, and a good rule for this purpose is to allow a head of not less than 100 feet, nor more than 300 feet, above the ground floor of any house. If you have less than 100 feet the pressure is scarcely sufficient for fire purposes, and if you have a greater head than 300 feet the pressure is so great that a very small leak means a serious loss of water.

Next as to the shape of a reservoir. The most economic way of enclosing a given area is by a circular wall. The new service reservoir at Kowloon is 150 feet diameter and 20 feet deep, its circumference is 471 feet; and to hold the same quantity of water in a square tank it would be necessary to build one of 133 feet each side, and this would give 532 feet length of walling or an extra length of about 60 feet. It seldom happens, however, that one is able to find a hill top at just the required level, and in building a reservoir on a hill side one must accommodate oneself to the nature of the ground. In the same way the most economic depth would be the same as the diameter; but here other considerations come in. With the reservoir full the water level would be too high, and with the reservoir empty too low; and further, a deep reservoir is much more likely to leak than a shallow one. Under ordinary circumstances, and with Chinese work, I think 20 feet is a reasonable maximum depth.

Now as to construction. In Hongkong a reservoir should, unless the ground is rock, be built entirely in cutting; much thinner side walls are then needed, and a decomposed granite hill is fairly water-tight at ordinary depths. The reservoir we are building at Kowloon has cement concrete floor and side walls, stone pillars carrying brick arches of 10 feet span; these again carrying concrete vaulting 11 feet span, one pipe serves as both in- and outlet. It is branched, however, at the reservoir, the inlet going in at the top and the outlet coming from the bottom, a reflux valve which allows the water to pass in one direction only being fixed on the outlet branch. A ball valve is fixed on the inlet which closes the supply when the reservoir is full, and as ball valves are rather given to getting out of order an overflow is provided which will discharge in a conspicuous place. A small washout pipe is provided for occasional cleaning of the reservoir.

In the old country service reservoirs are usually built on puddled clay and surrounded with puddled clay. I should not, however, care to try such a practice here. In the first place we manage to build perfectly tight tanks without it, and in the second place I am inclined to think we get much more trying periods of drought in the winter here than any experienced at home; this would dry and crack the puddle to considerable depths and probably cause leakage.

House Fittings.—It is now generally conceded that the constant system of supply is better than the intermittent system, and the question of house fittings consequently resolves itself into a consideration of pipes, taps, and water-closet fittings. The pipes used for this purpose are of wrought iron or lead; if of the former material they have screwed joints. They are connected to the main by a small screwed elbow called a "ferrule," a stop cock is usually placed in the street just outside the boundary line of the premises so that the supply to each house may be shut off separately. All taps should be of the screw-down type, being less liable to leak than plug taps, and through their requiring a longer time to shut, producing less shock in the pipes.

One of the best taps in use is that one invented by Lord Kelvin; its principal feature is a metal instead of a leather washer. This washer is held to the seating by a spring, so that after it has first taken its bearing it may be turned round a revolution or so and thus help to grind its own seating, and to pulverize any particles of grit which in an ordinary tap would prevent the washer from closing up to its seating. Another improvement on the ordinary tap is a small pipe so inserted as to carry away any water which finds its way upwards past the washer, and so obviate the necessity of any packing of the spindle. The Kelvin tap is probably as near an approach to indestructibility as is practicable; but the best of fittings require attention at times, and a tap is often classed as worthless when the fault lies with those who should have repaired or renewed it in time. In water closet fittings the chief aim of the sanitarian is to give the requisite flush and at the same time preclude the possibility of any connection between the drains and the water mains. For this purpose the service pipe, instead of being connected direct, is taken to a small open cistern above the closet, a ball valve shutting off the supply when the cistern is full. From the cistern a larger pipe leads to the pan of the water closet; any foul air which finds its way into the larger pipe will merely pass upwards through the water in the cistern and cannot gain access to the service pipes.

METERS.—Meters may be divided into two classes:—

(1) Meters for measuring town supplies, and waste prevention meters.

(2) House meters.

In the first class the "Venturi" meter is fast coming into favour, its great recommendation lies in the fact that it has no working parts in the water. It consists of two taper pipes fixed in the main, reducing the section of the stream and allowing it to expand again; at the point of greatest reduced section it is found that the pressure is considerably reduced, and this reduction of pressure is a measure of the quantity of water passing. In a gravitation supply the water can generally be measured over a weir; but for a pumped supply, and for long lengths of main in all supplies, it is desirable to introduce meters. By this means we learn at once if a leak has developed on the pipe line.

Waste prevention meters are for the purpose of detecting leaks in the mains or services of a town. In many places a leak may often go undetected through the water finding its way into the leaky joints of old and possibly disused drains. For the purpose of detecting such leakage, any district of convenient size is isolated by shutting the necessary valves, and a meter is fixed through which only the district can be supplied, this meter must record on a diagram the flow at any minute; its value then lies in the fact that during certain hours of the night little or no water is used. If then the meter shows a considerable consumption during the night, leaks must be looked for; but if the consumption is only small the meter may be removed to another district.

The question of house meters is one on which opinions are pretty evenly divided. There is no question but that the only absolutely just means of supply is by meter, a consumer then pays exactly for what he uses; but in practice many systems which are not absolutely just are eminently workable and convenient, and much cheaper than a perfect system. Let a house of say ten inmates use 20 gallons per head per day, or 73,000 gallons per year; with water at 25 cents per 1,000 gallons the annual charge will be $18.25. Now to measure this amount a meter costing at home £3.10.0 is required, and in Hongkong the very reasonable charge of $1 per quarter is made for it, so that if we adopt a meter system to prevent ourselves from robbing one another, we must tax ourselves to the extent of adding 22 per cent. to the cost of our water supply. Unfortunately there are in all places those who have no scruple about wasting water, if only the cost of their doing so is not brought directly home to them, and on this account rather than on account of its absolute justness, house meters have been largely adopted, and in all cases have been the means of largely reducing waste.

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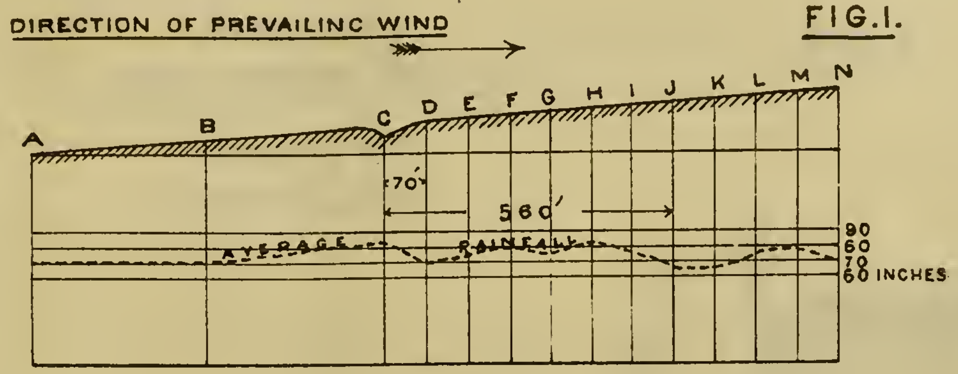
DIAGRAM SHOWING THE UNCERTAINTY OF RAINFALL

FIG. I.



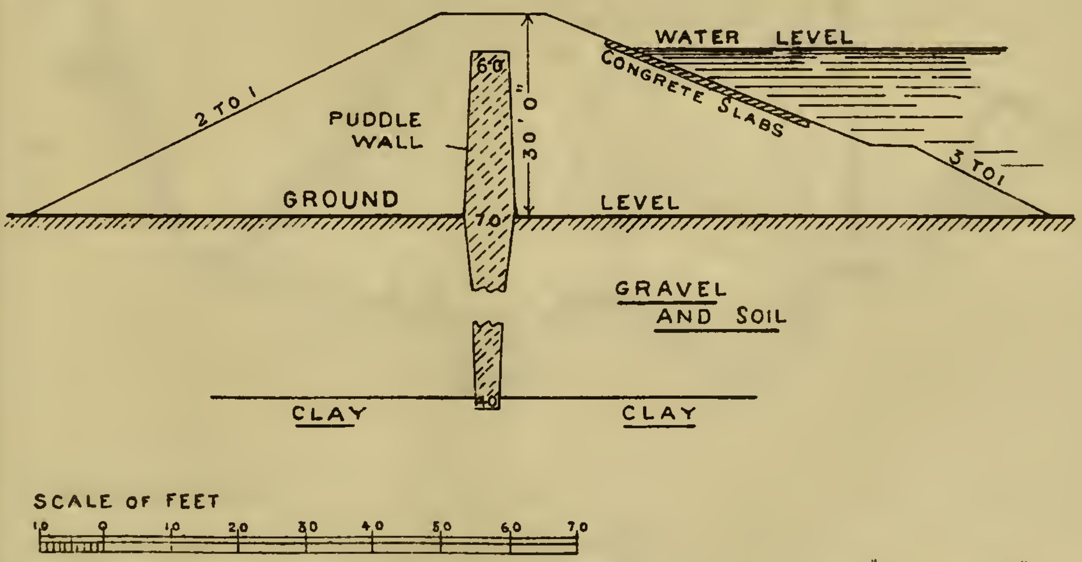
AVERAGE RAINFALL AT "C" IS 20% MORE THAN AT "D"
AVERAGE RAINFALL AT "C" IS 30% MORE THAN AT "J"

FROM "ENCYCLOPEDIA BRITTANICA" TIMES EDITION

NEW STAINES RESERVOIR

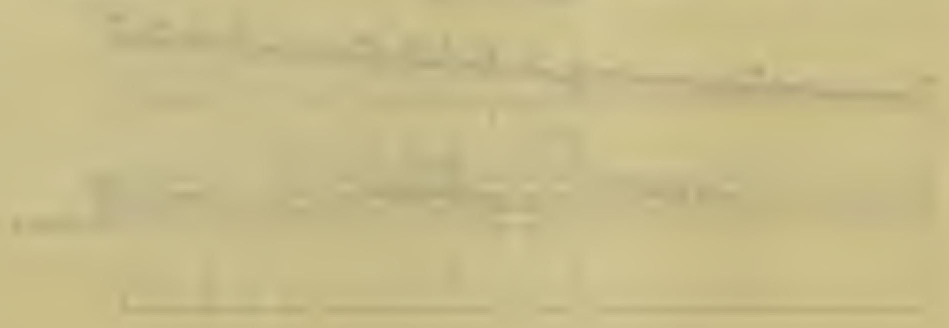
SECTION OF EMBANKMENT

FIG. 2.



FROM "THE ENGINEER"

[illegible]



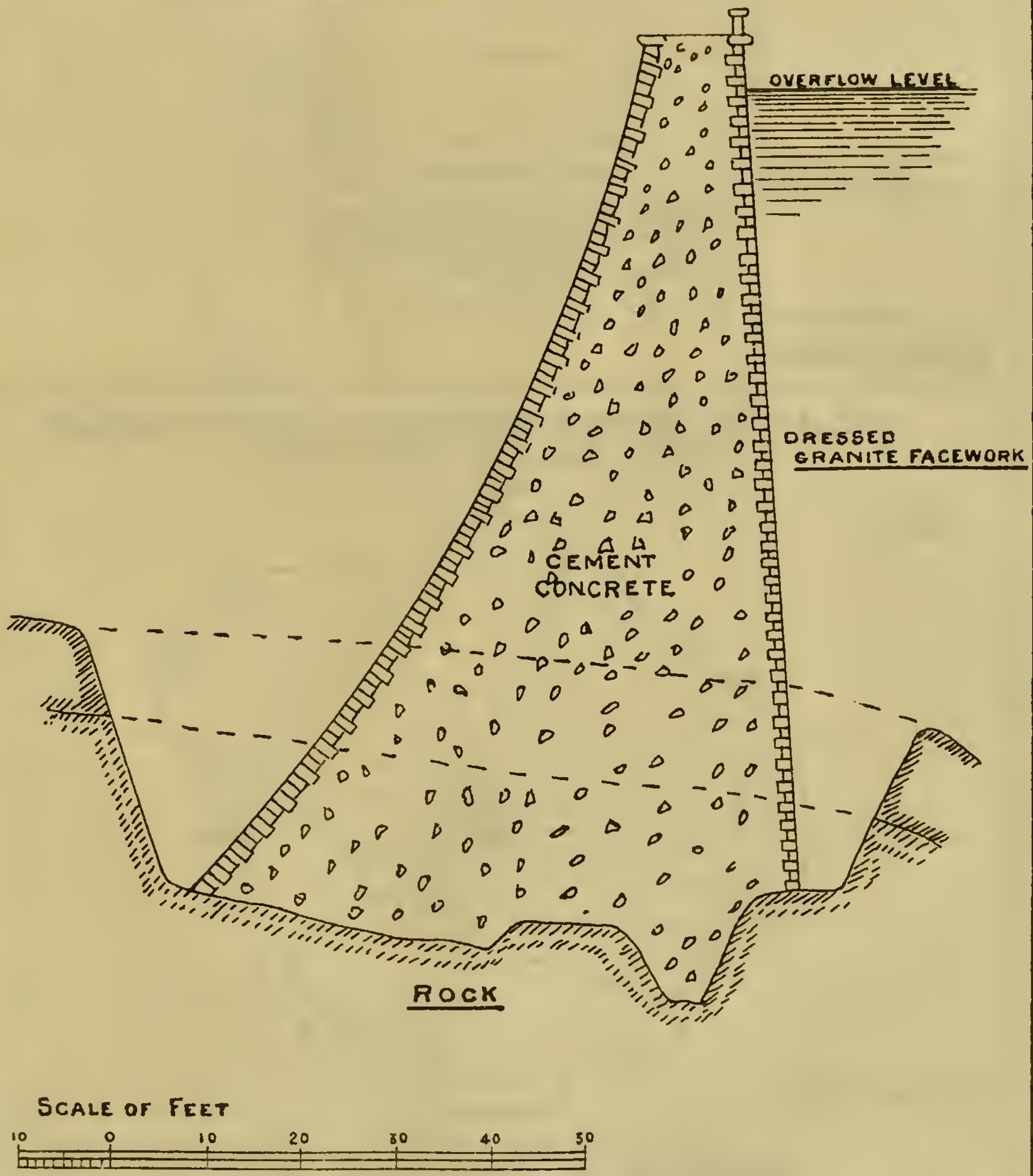
[illegible]

[illegible]

KOWLOON
NEW WATER WORKS

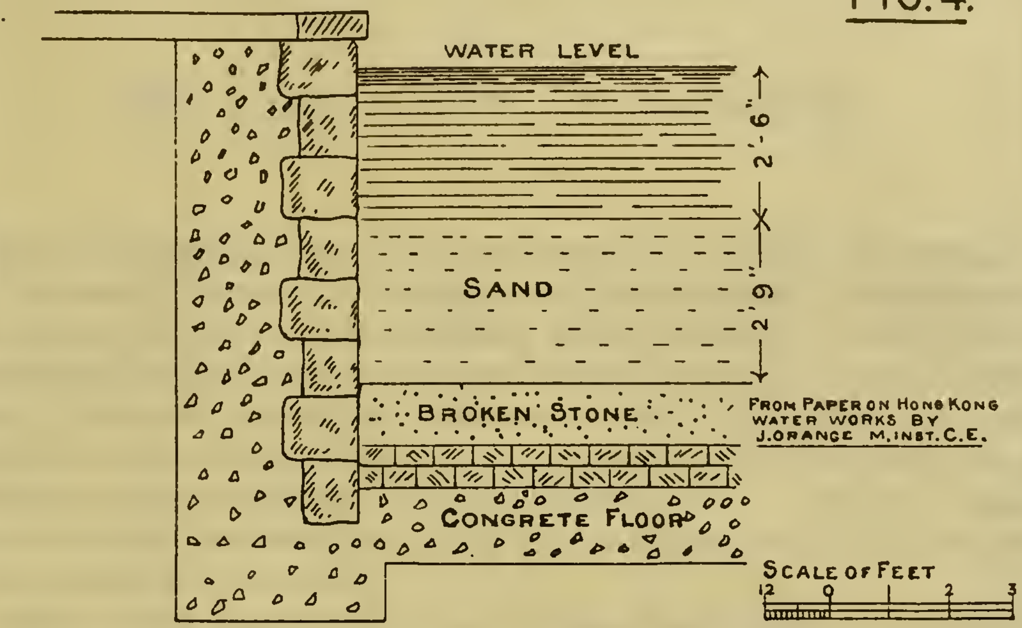
SECTION OF
MASONRY DAM

FIG. 3.



TYTAM WATERWORKS
ALBANY FILTER BEDS

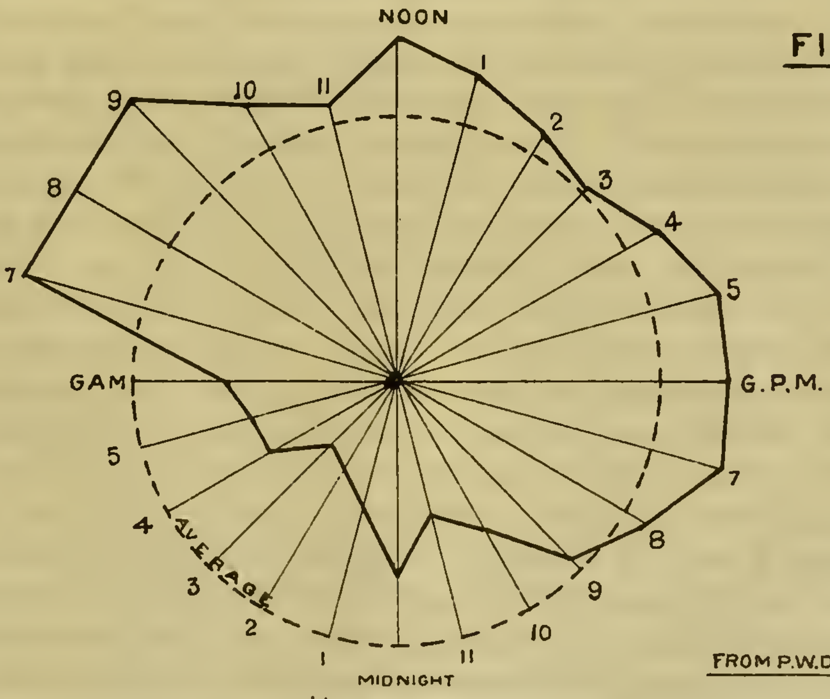
FIG. 4.



FROM PAPER ON HONG KONG WATER WORKS BY J. ORANGE M. INST. C.E.

DIAGRAM SHOWING CONSUMPTION OF WATER IN THE CITY OF VICTORIA 24. SEP. 1894

FIG. 5



FROM P.W.D. REPORT

TOTAL CONSUMPTION 3¼ MILLION GALLONS
AVERAGE HOURLY CONSUMPTION 135.000 GALLONS
MAXIMUM HOURLY CONSUMPTION 200.000 GALLONS

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

BUILDING MATERIALS

By JOHN LEMM, F. I. A. N. S. W.

IN order to keep the subject within the bounds of two single hour lectures, I have had to condense the information, and limit considerably the explanation of characteristics and qualities of different building materials. Descriptions of manufacture, methods of procuring, and cost, have, as a rule, not been included, except where such knowledge is necessary in better appreciating the items mentioned. Any attempt to describe the appearance and characteristics of all building materials would be an almost endless task, so only the common characteristics will be described in order that the student may have some idea of their peculiarities and uses.

Stone.—The durability of stone will depend upon chemical composition, physical structure, and position. Sulphuric acid, carbonic acid, and nitric acid in smoky towns decompose any stone containing carbonate of lime. Oxygen in ordinary air acts on stone containing iron. Crystallised particles are formed by the action of acids in the pores of stone, and these expanding break fragments from the surface, so that durability depends on relation of chemical composition of stone, to surrounding atmosphere to a great extent Pure atmosphere is better than one charged with smoke, or with acids calculated to attack the stone. These acids attack wet stone more readily than if stone is dry, so that rain has influence on durability; and stone on side facing prevailing rains will be more likely to decay quicker than on other sides. Any faces of stone sheltered from sun and breeze are liable to decay for same reason. Stone exposed to different degrees of heat on different faces is liable to crack from unequal expansion and contraction. Stones of crystalline structure weather better than non-crystalline, and finer grain is better than coarser, and is likely to be more durable, The stone should not contain soft patches or inequalities. Facility for working is of importance from an economical standpoint. Hardness of stone is necessary in places where much wear and friction occur, as in pavements, quoins with sharp corners, and in road metalling; but for carving a soft stone would naturally be selected. Stone used for work exposed to the action of water should be hard, as besides being exposed to the action of running water and impact of waves, sand and stones are thrown against the structure by the wind and sea.

Strength.—The strength should be ascertained if stone is to be subjected to unusual stresses, and should be ten times the compression to which subjected. Practically the compression that comes upon stones in buildings is never sufficient to cause any danger of crushing. The weakest sandstone will bear 120 tons per square foot, while in St. Paul's Cathedral the greatest stress has been calculated to be fourteen tons per square foot. In arches and retaining walls considerable pressure is concentrated on certain points. Heavy stones are best adapted for retaining walls, while light stones would be best for arches. Blotched or mottled stones should be regarded with suspicion, as unequal weathering may take place. Stone is better for being seasoned before being set, as seasoning gets rid of "quarry sap" or moisture in all freshly quarried stone. The working can take place when freshly quarried, but setting should be delayed. Stones in walls should be placed on their natural beds, *i.e.*, either as they lay in quarry, or turned upside down, as if the layers were laid parallel with face of wall, layer by layer will gradually be taken off by atmospheric influence. In arches the grain should be at right angles to thrust. In cornices the grain should be vertical, as top is exposed to action of weather; and it is a good precaution to cover top with lead to prevent wet getting into the joints. The natural bed is seen by position of imbedded shells and thin streaks of vegetable matter which generally show out better if stone is wetted. In some stones where stratification cannot be detected by the eye, the mason can generally tell by the "feel" of the grain in working. Under a magnifying glass the flattened particles are usually parallel to the bed. Worms in sea water have a mechanical tough shell augur, which bores into softer stones, and these worms also secrete a corrosive juice which dissolves the stone. Granite has been founed to resist these worms. The limestone blocks at Plymouth breakwater had, in consequence of worm attacks, to be replaced by granite.

Examination.—Fractures should be bright, clean, and sharp. Dull earthy appearance shows stone likely to decay. The best stones absorb the smallest quantity of water: sandstones after twenty-four hours immersion not more than 10 per cent. of their volume of water, limestones 17 per cent., granite 1 per cent.

Brard's Test.—The stone is immersed in boiling solution of sulphate of soda (Glauber's salts), and then hung up for a few days in the air. The salt forces pieces off stone, and the difference in weight of sample before and after experiment gives disintegrated amount, and the greater this amount the worse the stone.

Smith's Test.—Break off pieces (from damp stone), about size of shillings, put into glass about one-third full of water, and let it remain for half an hour. Then agitate by giving glass circular motion with the hand. If stone is crystalline and well cemented the water remains clear; but if uncrystallised earthy matter is present the water is turned turbid. Pulverised stone can also be used in testing. The weathering qualities of a stone may be judged from buildings erected, examination for chisel marks, or from face of the quarry from which stone was obtained. Blasting should be used as little as possible, as it shakes the stone and causes waste. Stones are divisible into three chief classes: (*a*) Igneous—*i.e.*, volcanic origin—such as the granites, traps, and syenites; (*b*) Aqueous—*i.e.*, deposited or formed in air or water—such as limestone and sandstone; (*c*.) Metamorphic—*i.e.*, rocks which have been subjected to great heat or pressure—such as marble and slate; or (1) Siliceous with base of flint or silica; (2) Argillaceous with base of clay or argile; (3) Calcareous with base of carbonate of lime.

Practical classification:—(1) Granites. (2) Sandstones. (3) Limestones. (4) Slate.

Granite—as name implies, is a stone of crystalline granular structure: true granite is composed of quartz, felspar and mica. Felspar predominates, then quartz, then mica. Quartz is hard, and glassy, and grey or colourless. Felspar is crystalline, and lustrous, and white, grey, yellow, red or brown. Mica is flaky and dark grey, black or brown. The colour depends on the predominating ingredient felspar. Durability depends on the quantity of quartz and nature of felspar. If much quartz is present the stone is hard to work, but weathers well Mica is easily decomposed and is a source of weakness. If iron stained considerably the stone should be rejected. Smaller grained granite is more easily workable and wears better.

Syenite—is usually included in the granites, and consists of quartz, felspar and hornblende (which takes the place of the mica in true granite). It takes its name from Syene in Upper Egypt. Syenite is generally darker than true granite due to the hornblende; and the syenitic granites, containing a little mica as well as hornblende, take a fine polish and are very durable. Granite is quarried by wedging or blasting. It is better to dress in quarry while sap is in stone; dressed stone is less heavy than unprepared stone, and as granite is so hard it is not liable to be injured in carriage.

Uses of Granite.—Used for bridges, piers, docks, breakwaters, lighthouses, paving, and road metal, polished columns, heavy plinths, etc. The granular structure renders it unfit for fine carving, and its surface is entirely destroyed by the effects of fire. Aberdeen granite is generally grey; Peterhead granite is generally red; Hongkong granite is generally grey.

Trap Rock.—Greenstone or Whinstone is composed of felspar and hornblende, and is generally of greenish colour, very hard and tough, and makes good road metal.

Basalt—resembles greenstone, and is used for paving.

SANDSTONES—are composed of grains of silica cemented together by carbonate of lime, etc., and also contain oxide of iron (which gives colour), mica, and clayey matter. The durability depends on the quality of the cementing material.

CLASSIFICATION.—Flagstones are those with good natural cleavage. Freestone is a term applied to any stone easily worked with chisel and mallet. Grits are coarse grained, strong, hard sandstones. The fracture should be bright, clean and sharp, and grains uniform in size; and a first class sandstone should hardly do more than cloud the water under "Smith's" test. Finer grained stone wears better than coarser grain.

USES.—The hardest are used for important ashlar work; finest and closest grained for carving; rougher qualities for rubble; well bedded varieties for paving. It is not good for road metal as it becomes muddy in wet, and dusty in dry weather.

LIMESTONES.—The term is applied to any stones the greater portion of which consists of carbonate of lime. Chalk, Portland stone and marble consist of nearly fine carbonate of lime. Many of the most easily worked limestones are soft when first quarried, but harden upon exposure. This is partly due to decomposition of the softer particles, leaving harder particles a protection; but the escape of "quarry damp" has possibly the greater effect in the hardening process. When magnesia is present in limestone, the stone is then known as "Dolomite." Limestone is burned largely for plastering purposes.

MARBLE—is the name given to any limestone which is hard enough to take a fine polish; and is used for chimney pieces, slabs, inlaid work, columns, and for sea walls and breakwaters where cheaply obtainable. It is not good for road metal as it is too brittle and very greasy in wet weather, and dusty in dry. The colour is due to metallic oxides, and from shells, corals, etc., embedded in the composition. Many of the marbles used by the ancients and handed down in works of art, are not now known in their natural state.

SERPENTINE—derives its name from mottled appearance (supposed to resemble serpent's skin). It is generally of a rich green or red colour, permeated by veins of white. Soapstone is a kind of serpentine. It is easily worked, receives a fine polish, and is used for decorative purposes for interiors. Compact limestone is generally devoid of crystalline structure, of a dull earthy appearance, and of a dark blue, grey, black or mottled colour. It is good for building purposes, where colour is not an objection.

GRANULAR LIMESTONE.—Carbonate of lime with silica or alumina is generally soft and absorbent, but used in England as one of the principal building stones. Some of the principal varieties in use are Bath stone, used for mouldings and carved work, and of white to light cream colour. Portland stone is usually light brown, and of four varieties, and has been used in west front of St. Pauls, Somerset House, General Post Office, Horse Guards, and many important buildings.

KENTISH RAG—is used for rubble work and paving, and is a very compact, heavy stone, absorbs very little water, and weathers well.

ARTIFICIAL STONE.—Where difficult to obtain natural stone at a moderate cost, artificial stone may be used. Ransome's Artificial Stone is made by mixing sand, dissolved flint, and powdered chalk, in a pug-mill, then forced into moulds, and pores filled under pressure with chloride of calcium solution, and is used for most purposes.

VICTORIA STONE—is washed finely powdered granite, bound together with Portland cement, and then hardened by immersion in silicate of soda. It is used for paving, as cheaper and more durable than Yorkshire stone flags, and is also used for stairs, landings, troughs, tanks, sinks, etc. There are many kinds of artificial stone on the market.

PRESERVATION OF STONE.—The preparations for preserving stone are divided into two classes. The first consists of dissolved organic substances which fill up the pores of stone and preserve it for a time; but they themselves are liable to decay, so only temporary preservation is obtained. The second class are solutions of substances which combine with the constituents of stone to form solid compounds. The stones should be heated and placed in vacuum chambers, but this is often impracticable. Paint preserves stone for a time (about 3 years). Oil preserves stone but discolours it. One and a half pounds of paraffin dissolved to one gallon coal tar and applied warm is recommended if colour is not objectionable. Beeswax dissolved in naptha or camphine is also good. To preserve statues and marble exposed to air, melt two parts of wax in eight parts pure essence of turpentine. Surface is to be cleaned with hydrochloric acid and water, dried, and then coated with the solution. Many preparations contain soluble silica, but efflorescence is caused on walls by use of these substances, causing disfigurement. Ransome's Indurating Solutions have been used with success for preservation of stone from decay, and to keep out damp in St George's Hall, Liverpool, Trinity College, Dublin, and many public and private buildings.

SLATE—is compact and fine grained, and splits readily. The rock is worked by tunnelling, then blasted, split into 3 in. thicknesses, cut by saws, and split by chisels. Good slates should be hard and tough, and non-absorbent. If too soft moisture is absorbed and nail holes become enlarged. It gives out sharp metallic ring when struck with knuckles. The colours vary, but most frequently are dark blue, bluish black, purple, grey, and green. Black varieties are more absorbent and likely to decay. The grain in good slate should be very fine. The veins are objectionable and conduce to splitting. Sizes are distinguished by special names: from Empresses 26 in. × 16 in., to Ladies 16 in. × 8 in., to Singles 10 in. × 8 in.

through many stages. A good slate should not absorb more than $\frac{1}{200}$ of its weight in twelve hours. Slate slabs are obtainable up to 20 ft. × 10 ft. Slabs are used for cisterns, urinals, troughs, mantels, baths, skirtings, floors, steps, landings, dampcourse, etc. Enamelled slate is prepared by painting, baking, enamelling, rebaking, rubbing and polishing, and often imitated to resemble marble.

Bricks.—Bricks are an artificial kind of stone, made of burnt or baked clayey earth, and the quality of the bricks depends on: (*a*) chemical properties of the earth; (*b*) preparation of the clay; (*c*) different degrees of burning. The chemical composition of brick earth is: silica, *i.e.*, flint and sand three-fifths; alumina or clay one-fifth; and traces of iron, lime, magnesia, manganese, soda and potash one-fifth. Alumina is plastic when damp, and contracts with heat. Silica produces hardness and prevents shrinkage. Lime acts as a flux causing particles to unite. Magnesia influences colour of the bricks. Clays from near sea shore are not suitable for bricks and cause warping and twisting with liability to absorption. Plastic or strong clays contain silica and alumina and to allow of being used must have lime added. Loamy clays contain an excess of sand and must have lime added. Marls contain a large proportion of lime and can be used without addition of other substances. Malm is an artificial preparation of marl. The brick-making quality of a clay is best tested by making a brick and burning in a kiln. Brick making operations may be divided into: (1) preparation of the brick earth; (2) moulding; (3) drying and burning.

Preparation of earth: (*a*) unsoiling, *i.e.*, removing top mould (known as encallow, and operation as encallowing); (*b*) clay digging; (*c*) stone picking. The clay is dug in autumn and piled up 2 ft. on ground and stones picked out. (*d*) weathering, *i.e.*, brick earth with layers of breeze and chalk up to 5 ft. high and left till summer; (*e*) grinding, to get limestone crushed out; (*f*) tempering, *i.e.*, turning earth over and kneading with shovels, treading out or passing through a pug mill.

Moulding is to give bricks a definite shape. The mould is 10 in. × 5 in. × 3 in. for a brick $8\frac{3}{4}$ in. × $4\frac{1}{4}$ in. × $2\frac{5}{8}$ in. as clay shrinks one-tenth in all directions. The mould is wetted or sanded to prevent brick adhering. The moulder then dashes in tempered clay and strikes with a fine fillet (16 in. × $1\frac{1}{2}$ in. × $\frac{3}{8}$ in.) all superfluous clay over and above the top of the mould. Drying is to evaporate moisture, and to allow brick to be handled without injury when stacking in the kiln or clamp. Slop or wet moulded bricks are taken in the mould and put on a drying floor which is convex and covered with a roof; the bricks are then sanded, left one day, turned on side, left another day, and then wheeled to the hacks. The hacks are long paralled banks, 6 in. above ground, made of brick rubbish or ashes, or of drainpipes covered with thin concrete bed.

When sand moulding is used, moulder places a board or pallet ⅜ in. thick and 1 in. wider than brick on top of brick in mould, turns mould over, releases mould, and brick is taken on the pallet to the hacks. Bricks are hacked ⅜ in. apart, built about seven courses high, ends exposed to weather, laid on one narrow face. After ten days they are scintled, *i.e.*, laid at an angle of 45 degrees to length of hack, the directions of successive courses being reversed and a space of 2 in. left between bricks. Whole drying takes three to six weeks, and the hacked bricks are protected by wood framing covered with straw matting, screens, or tarpauling.

Burning—is to enable bricks to withstand atmosphere and compression, and to give colour. Bricks are either burnt in a clamp or kiln. A clamp is a stack of raw bricks surrounded with burnt brick sides forming a truncated quadrilateral pyramid, with flues to admit of fuel being burnt therein. The clay should have breeze or cinder intermixed, which constitutes part of fuel for burning, and such bricks are known as Stocks. Stocks are generally employed for internal parts of walls, and sometimes best stocks are picked for facings. Burning in clamp takes from two to six weeks, and burning finished when top settles in.

Kiln—is a prepared brick chamber with flues (with or without a roof), the usual sizes containing from 20,000 to 50,000 bricks, and the stacking and burning is finished in two to three weeks.

Indications of Processes:—The following hints are useful in determining some of the processes which a finished brick has passed through.

Hand moulded.—Frog on one side, no great amount of finish in the form, and porous.

Machine made.—No frogs, wire marks on beds regular in form and dense.

Pressed bricks.—Smooth faces, sharp arrises, clean frog or frog on both sides, trade marks in frog, very dense.

Clamp burnt.—Colour of bricks not uniform, traces of breeze can be seen, especially when bricks are broken across.

Kiln Burnt.—Light and dark stripes upon the sides caused by bricks being arranged with intervals between while burning, the exposed parts are burnt light colour, and where resting on other bricks dark colour.

Kiln burnt bricks are more equally burnt and more uniform in colour (fires can be regulated to prevent warping), and are more economical through saving of time than clamp-burnt bricks. The colour of bricks is affected: (*a*) by chemical composition of earth; (*b*) by sand which has been sprinkled on brick; (*c*) by degrees of heat during burning; (*d*) by quantity of iron in the clay. Bricks made from clay which is free from iron burn white. Clay with small quantity of lime with iron, burns yellow; clay with small quantity of lime, more iron, burns red; clay with large quantity of lime with iron, burns brown; 8 per cent. to 10 per cent. of iron in clay causes bricks to be black or blue. Red clay with alkalies burns bluish green (as in Staffordshire bricks). As a rule the greater the heat, the darker the tint. Bricks may be classified as: (1) clamp burnt; (2) kiln burnt. Clamp burnt are of three kinds: Malms, Malmed and Common. Malm is prepared brick earth mixed with breeze. Malmed earth is malm clay mixed with unwashed earth. Common brick earth is the name given when no attempt is made at washing of clay. Cutters or Rubbers are made from clay soft enough to be cut with wire saw. Facing Paviors are malms of good shape for superior work. Hard Paviors used for paving, coping, etc. Shippers are sound, hard burnt, imperfect in form, and used by ships as ballast. Stocks are clamp burnt bricks, hard, fairly sound, and used in ordinary work. Hard Stocks are overburnt, of blemished colour, and used for pavings, footings and interior of walls. Grizzles are underburnt but sound bricks of good form. Place are underburnt bricks, but are weak and used in temporary work. Chuffs are hot bricks cracked by rain. Burrs are bricks vitrified and run together. Bats are broken bricks.

Special Varieties.—Gault bricks are made from bluish Gault clay. White Suffolks made for facing. Fareham Red bricks are from pure clay or soil, and are used for ornamental arches, etc. Dutch Clinkers are made 6 in. × 3 in. × 1 in. for paving. Enamelled bricks have white surface like china, produced by a thin coating of white material, and are used in lavatories, dairies, etc., and to reflect light, as in underground railway stations. Salted bricks have their glaze produced by salt being thrown into fire during progress of burning. Fire bricks are so named on account of their resistance to great heat, and resistance depends on proportions of mixture; they are yellow in colour and close in texture. The loam from which they are made is of yellow colour, containing much sand, and found generally (as at Stourbridge) under coal measures. They are highly serviceable for furnaces and ovens. The clay is "refractory," *i.e.*, capable of standing high temperatures without becoming soft. Characteristics and tests of good bricks are regularity of size and shape, rectangularity of faces (one end and side only need be smooth), uniformity of texture, compactness and freedom from flaws.

Absorption by a brick when saturated should not exceed one-seventh of its own weight, and moisture should be parted with freely at moderate temperature. Bricks should be uniformly burnt, give metallic ring when two are knocked together (a dull sound shows a soft or shaky brick), should be of good colour, sound when broken, pasty in texture (not granular), they should require repeated blows before breaking, and stand cartage and handling. An underburnt brick can be easily scraped with a knife. Machinery produces bricks more cheaply than by manual processes. Pug mills are used for tempering clay. Grinding machines for crushing fragments. The clay in forced through an orifice and cut by wires in wire-cutting machines. Some machines do these three operations together. Dry clay machines press the powdered clay into well-shaped bricks with even surfaces, and this method is well adapted for stony or marly clays, and saves drying before burning. The frog in bricks affords a key for mortar, and in laying the frog is put uppermost, unless where a course is to receive a damp-proof layer. Moulded bricks are made for cornices, plinths, etc., and up to elaborately decorated diaper patterns, panels, etc. Large bricks are inconvenient for an ordinary man's grasp, and fatigue the bricklayer who uses one hand for laying. In order to obtain good brickwork, it is important that the length of each brick should equal twice the width plus one mortar joint. Hollow bricks are made for hollow walls, and tubular bricks are made for column building. Paving bricks are made plain and with flutes and diamond pattern. Channel bricks are made of various sections. Cattle shed bricks are of channelled section placed together, and liquid runs along gutters in centre.

TERRA COTTA—is formed of different clays mixed together, with a proportion of ground glass, pottery, and sand added. The mixture is reduced to fine powder, thrown into water, pugged, kneaded, forced into moulds smeared with soft soap, dried, baked in pottery kiln, and slowly cooled. Blocks for building purposes average 1 to 3 cub. ft., and no block should exceed 4 cub. ft. Blocks are made hollow with Terra Cotta 1 to 2 in. thick, with partitions; and if blocks are to bear weight the spaces are filled in with brick and cement. Blocks are made to bond into brickwork readily.

Advantages of Terra Cotta: durable, light, strong, hard and cheap.

In paving, experiment has shown that Terra Cotta lost $\frac{1}{16}$ in. in thickness when York stone lost $\frac{1}{4}$ in. with same amount of friction. Disadvantages are unequal shrinkage in burning, and when outer covering destroyed inner material does not stand atmosphere. Colour white, pale grey, yellow when poorly burnt, and pink and buff when well burnt. Green is a sign of bad material. Terra Cotta may be glazed.

STONEWARE—consists of 76 parts silica (flint or sand), and 24 parts alumina (clay), with very little infusible matter, mixed with powdered stone, ground granite or sand, and burnt in kiln like fire clay, but at higher temperature. Stoneware is vitrified throughout, hard, dense, and rings well when struck. Stoneware articles are often salt glazed, but will resist moisture without glazing. Stoneware is useful for all purposes to resist atmospherical, chemical or other destroying influences. Unglazed earthenware from brick clay is weak and porous. Fireclay ware should be glazed, and is inferior to stoneware for pipes.

Stoneware is best material for sanitary ware, sewer pipes, and vessels to contain chemicals. Terra Cotta is inferior to stoneware, but better than earthenware or fireclay ware. Glazing is sometimes done for appearance, but more often for protection from action of atmosphere, and destroying agents. Glazes are either transparent (a thin film of glass), or opaque like an enamel. Salt glazing is effected by throwing salt into furnace when articles are at a high temperature, and the chemical action forms a glass covering. It is used for stone ware and fireclay articles. Lead glazing is carried out by dipping the article to be glazed (after first burning) into a bath containing lead, tin, borax, etc., ground to powder. The article is then withdrawn and reburnt. The second burning turns the mixture to glass. Lead glazing is used for glazing Terra Cotta.

OPAQUE GLAZING.—The article is dipped into a slip formed of superior clay, finely worked and dried, brought to colour required, and burnt. Water closet pans are made white inside and yellow outside by this process.

PIPES—are made from finely ground washed and tempered clay forced by machinery through a mould, dried, and baked in a circular kiln. Sewer pipes should be of stoneware (preferred), or fireclay, sufficient to resist fracture, tenacious, hard, impervious, uniform, straight, or properly curved, glazed with salt glaze inside and outside, free from flaws, and pipes should ring well when struck. Sockets to pipes are sometimes formed separately, but should be made in same piece as pipes. Smaller pipes are usually 2 ft. long; the 4 in. diameter will be ½ in., the 6 in. diameter will be ⅝ in. thick stoneware, larger pipes may be obtained up to 30 in. diameter and of 2½ to 3 ft. lengths. Bends, taper pipes for joining two pipes of different diameter, single and double junctions, saddles and chairs for piping, lidded pipes, and syphon traps are all readily made from stoneware. The impermeability of pipes may be simply tested by tieing a piece of bladder over one end, reversing, and filling with water; if not impervious water will issue through pores of pipe. Other methods are explained in "HOUSE DRAINAGE" lecture. Test for chemical action is made by pulverizing pieces of pipe, boiling in hydrochloric acid, and noting loss in weight. In stoneware these experiments showed that no loss occurred. Perforated air bricks are made from 9 in. × 3 in. to 18 in. × 18 in. Perforated damp-proof courses, bonding bricks, made to prevent water getting along brick, wall facing materials, and sleeper blocks for carrying floors in damp situations are made in stoneware and Terra Cotta; flue pipes, single and in combination with air flues, chimney terminals, inverts for sewers, gully traps, and sanitary apparatus of every form and variety are made from stoneware.

TILES.—Building tiles may be divided into two classes: (1) common tiles for roofing and paving; (2) encaustic tiles for decorative purposes. Common tiles are made from somewhat similar clay to brick earth; the clay is weathered by exposure, allowed to mellow in pits, tempered, pugged, cleared from stones, beaten with wooden bat to prevent warping, and burned in domed kilns. Paving tiles are made in squares, hexagons, etc., from 6 in. × 6 in. to 18 in. × 18 in. and from ½ in. to 2 in. thick. Flooring tiles are sometimes known as "Quarries."

Roofing Tiles.—Tiled roofs are heavy, are apt to absorb water, and to keep roof wet. To prevent this the tiles should be glazed, but this makes the tiling too expensive. Many descriptions of roof tiles do not fit closely and require pointing.

Plain Tiles—are flat, either rectangular or cut to various patterns, these are fixed to battens by small pegs or projections on upper part of tile. Pantiles are moulded flat, and bent to form required over another mould, and in English tiles hung to battens by a stub. Double roll tiles and corrugated tiles are made by curves with extra stubs on same. Taylor's patent roof tiles are formed by channels and caps. Venetian or Italian tiles are pan and roll tiles as used in Hongkong. Ridge tiles are made to fit ridges, and hip and valley tiles are made to fit hips and valleys. Wall tiles are glazed of different colours, and in some cases are fixed by nails through tiles into joints of brickworks, in other cases simply bedded in cement. They are used where light is important, as in areas, or for cleanliness, as in dairies, bath rooms, etc.

Encaustic Tiles—are those in which the colours are produced by substances mixed with the clay, not printed on after tile is made. These tiles are made from ordinary or mud clay carefully prepared. The clay is first prepared, then mixed with colouring matter and slipped or passed through fine muslin or silk sieves, boiled in kiln until plastic, pieces knocked together to drive out air and consolidate the clay, and then kept for several months until organic matters disappear. The clay is then cut by wire into long pieces. Each tile has three layers: (1) the face of fine clay of colour required; (2) the body of coarser clay; (3) the back of different clay from body. The face clay is ¼ in. thick and slightly larger than size required to allow for contraction in burning. The face is pressed on to a Plaster of Paris slab with pattern in relief, and indentation obtained; then backed with coarser clay, and then layer No. 3 put on, maker's name stamped on, and tile grooved to adhere to rendering. Slip clay of colours required is then formed into indented pattern, and after it becomes partly hard the raw tiles are then trimmed, dried, and baked in ovens protected from smoke (in jars called seggars). The tiles may then be glazed by dipping into a mixture of powdered glass and water, and reheating.

Inferior Encaustic Tiles.—In these instead of colour being burnt in along with clay, it is transferred to surface of tile, and to give appearance of inlaid colour, a little colour representing depth of inlaying is applied to the sides of the tiles. These tiles are sometimes glazed and serve for flower boxes and wall tiles.

Dry Tiles.—Clay is prepared, mixed with colour, slipped, dried and reduced to powder, and then under pressure from a steel die consolidated. At same time any pattern is impressed. Then tile is dried, glazed and fired.

Tesserae—are made by dry process for mosaic purposes. Majolica tiles have raised patterns, and colour is applied as an opaque glaze; these tiles are not generally used for paving.

Mosaic Paving Slabs.—Made by arranging tesserae on pattern required in wooden frame, then Portland cement run in on back, and then two layers of common tiles in cement added to form slab. Flat encaustic tiles are used for paving or wall decoration. Raised encaustic tiles are used for decoration only. In some cases the tiles are put together in panels, then the picture is painted, the tiles are separated, and burnt and glazed. Cement tiles are made by pressure, and those made locally are not burnt.

Limes and Cements.—Limes and cements are made from burning limestones or other calcareous material, the effect being to drive off the carbolic acid and moisture contained. Calcination is heating to redness in air; quicklime or caustic lime remains after calcination. Slaking is the process of chemical combination of quicklime with water. Slaked lime is the substance remaining after slaking and chemically known as "hydrate of lime"; setting is the hardening of lime after mixing with water. Drying means water evaporation, but not setting. Hydraulicity is the property which mortar possesses to set under water, or in positions free from access of air. Limestones differ in composition, ranging from those containing fine carbonate of lime (as in white chalk or marble), to stones containing 10 to 30 per cent. of clay, besides lime, magnesia, iron, etc. Impurities, if soluble in acids, help setting. Fat or rich limes—such as shell lime—are those in which insoluble impurities do not exceed 6 per cent. Rich limes are best for sanitary purposes, being purer, and for plastering and whitewashing. In poor limes the insoluble impurities equal 15 to 30 per cent.; poor limes take longer to slake, do not increase so much in bulk, and take up small quantity of sand. The paste is incoherent and should not be used if better is obtainable. Hydraulic limes contain a quantity of silica and alumina, which render the lime independent of external agents for setting properties. Feebly hydraulic limes contain 6 to 16 per cent. of impurities; hydraulic limes contain 16 to 26 per cent. of impurities. Eminently hydraulic limes contain 26 to 36 per cent. of impurities. Oyster shells require burning at a high temperature. They contain gelatine which is converted into charcoal and burns with difficulty, and the result is to produce a badly slaking lime.

Lias lime is from a raw stone of dark blue colour, and the burnt lime is a pale grey. Fat lime and clay mixed in proper proportions will produce artificial hydraulic lime. Twice kilned lime is ordinary limestone burnt, then mixed with clay and reburnt. Best plan to judge limestone is to burn stone and try the lime. Limestones are burnt in kilns of various shapes, the most common being cylindrical, lined with fire brick, having a drawhole to apply the fuel. A rough dome of limestone is built with chamber for the fire, and top of dome usually covered by a shed. In burning limestone the heat is applied gradually, otherwise the separation of the carbon dioxide takes place with such violence as to burst the stones. The stones should be withdrawn from the kiln directly the dark red colour changes to a brilliant white glow. If over burnt the lime will be very difficult to slake and the lime is unreliable, as it would probably blow when bedded in the work. A somewhat similar result occurs with underburnt lime. Slaking is induced by adding water to quicklime, these on combining give off great heat and form steam, causing lime to expand, burst and disintegrate, and in this condition it is soluble when saturated, and in fit condition to combine with CO_2 or carbon dioxide to form crystals.

If quicklime is left exposed to air it absorbs CO_2 which under these conditions renders it inert, as the resulting effect is not crystalline. It is important that all particles be water slaked, as any unslaked parts will disturb the work. To obviate this failing mortar should be kept for about fourteen days before being used. Sand is added to lime in preparation of mortar: firstly to counteract excessive shrinkage, secondly to allow ducts for CO_2 to act upon lime, thirdly to increase bulk as sand is cheaper than lime. Sand for mortar should be free from earthy or clayey matter, should have sharp angles and rough surface. Best sand is pit sand, then river sand; the grains of river sand being rounded and smooth do not adhere so well, but this sand is used in plasterer's work, because of its fine light colour. Sea sand should not be used for plastering or building work, as it effloresces and causes wall to be permanently damp. Sand should be screened and sifted before use, loamy or dirty sand should be washed by placing the sand in a vessel through which a stream of water is passing, the sand being agitated to separate foreign matter which is washed away. Sand for all sorts of plasterer's work should be thus washed. Clean sand should leave no stain when rubbed between the moist hands, and salts can be detected by taste, while size and sharpness of grains can be judged by the eye. Crushed stone used for mortar in lieu of sand is found to be 50 per cent. stronger, than when plain sand is used. Pozzulana is a name given to clayey earths containing 80 to 90 per cent. clay with a little lime, magnesia, potash, etc., and may be added to fat lime with advantage, tending to confer hydraulicity. Disintegrated granite has the properties of crude pozzulana, and when clean is better than inert sand for mortar mixing.

SETTING OF MORTAR.—The chemical crystallisation goes on until the whole is set; the crystals have a tendency to adhere to something rough and hard, and for this reason the addition of sand increases strength of mixture, the best ratio being one of pure lime to one of sand, and the maximum should not exceed three of sand to one of lime. A long time elapses before pure limes harden, owing to their depending upon external aid to attain this state. If pure lime only is used the surface would set, forming a layer, and the interior would simply dry to a powder without setting; so that pure lime mortar should be avoided.

HYDRAULIC LIMES AND CEMENTS.—These do not depend on external agencies for setting properties, but set in centre of walls and under water, and should be used in all constructional work. Plaster of Paris is produced by calcination of Gypsum, a soft stone of crystalline texture varying in colour from white to black, found in England, but in great abundance near Paris. The fine grained white variety is termed Alabaster; the transparent variety is termed Selenite. This is the only building material which at the time of setting expands in volume, so it is valuable for filling up holes and other defects. It is used for ornaments for ceilings, and may be used where not exposed to water. Mixed with ordinary limes it arrests slaking and increases rapidity of setting. Selenitic lime or cement is made by adding limes of lias formation or hydraulic lime of any description to plaster of Paris, and is used for mortar, plastering, and concrete. Keene's cement is prepared by mixing plaster of Paris to a solution of alum, and then baking to drive off water. It is used for skirtings, angles and hard plaster. Parian cement is gypsum and borax (calcined). It sets in four or five hours, does not effloresce, and has hard translucent surface. Roman cement is a natural cement, prepared by burning nodules found in the London clay, and in shale beds. It contains 40 per cent. of clay and should be used fresh. It is about one-third strength of Portland cement, and sets in fifteen minutes, and is used in tidal works. Natural cement contains from 20 per cent. to 40 per cent. of clay. Portland cement so called from fancied resemblance to Portland stone is an artificial cement and should contain 60 per cent. of lime, 20 per cent. of silica, 5 to 10 per cent, of alumina, and small quantities oxide, etc. These combined produce "slurry"; the slurry is dried and moisture extracted. The slurry is then burned in a kiln to produce "clinker"; clinker is then crushed and elevated into hoppers, passes through the mill and becomes finished cement. The finer the cement the less weight, and it will be stronger, consequently weight and fineness should be considered in judging quality.

(*a*) 75 per cent. of cement should pass through a sieve having two thousand five hundred holes to a square inch. (*b*) Weight should be 110 to 115 lbs. per striked bushel; the striked bushel is a measure containing 1.28 cubic ft. lightly filled (21=cubic yard). (*c*) Good cement is grey, or greenish grey; brown or earthy colour indicates too much clay, coarse bluish grey would be over-limed. Colour is best judged by rubbing on hands or spreading on paper. Tensile strength is judged by proper machine, with briquettes 1½ in. square. (*d*) Average= 350 lbs. per square inch. in seven days after briquette of neat cement being made in a mould, and immersed in water during the entire interval, and the mean of six briquettes should be taken. (*e*) Coolness: if too much lime, or underburnt cement, has a tendency to crack and swell, and this condition will be indicated by cracks on edges of briquettes. (*f*) Pratical test.—Plunge hand into bag of cement; if cold it is dead and useless, if hot it has not been sufficiently exposed to air, if blood heat it is fit for use. (*g*) Bottle test:—Mix a quantity and fill a bottle, and cork while wet. If too fresh it will expand and crack bottle; if stale, it will shrink and rattle on setting; if in proper state it will not crack bottle or shrink.

Storage.—Cement in dry temperate climate should be spread out to a moderate depth, say 3 ft., for a month on a wooden floor, and turned over occasionally in order that particles may become air slaked and cooled. In moist climates the cement would probably be deadened by this treatment.

Mixing.—Cement should be mixed with as little water as possible and used immediately, and on no account to be left to commence setting or to be worked up a second time. The materials to be cemented together should be clean, free from loose particles, well soaked in water before use in order that they may not absorb the water out of the cement mixture. Cement does not slake like limestone. Cement is used for foundations in wet places, dock walls, lighthouses, concrete, mortar copings of walls, tops of chimneys, cesspits, drain joints, protection of walls from weather, in thin walls where strength is required, pointing, filleting, paving and rendering. More than 40 per cent. of clay injures cement; with more than two-thirds clay cement will not set under water. German cement is ground finer than English, and some kinds are so fine that 90 per cent. go through a sieve with meshes 32,000 to the inch. The fine cements are used chiefly in patent paving; in very heavy cements there is some danger of excess of lime, which renders it unfit for sewer joints. Quick setting cements set in fifteen minutes, slow setting cements set in two hours, very slow setting cements set in five hours; but age, temperature, and quantity of water used all have effect on time of setting. Imported cement is sold by cask usually 27½ in. long by 19 in. middle diameter by 16 in. end, diameter, and each contains 400 lbs. net. Green Island cement is sold at present in casks 375 lbs. net, $4.75 ex factory, in bags 250 lbs. net. $2.85 ex factory. In the absence of proper lime, in lieu of lime mortar, cement mortar composed of one part cement to eight parts sand may be used with advantage.

Lime Mortar.—Lime mortar is composed of lime and sand mixed to a paste with water. Cement mortar is cement and sand mixed with water. The use of mortar is to bind together bricks or stones in brickwork or masonary, to prevent inequalities resting on each other, to obtain equal pressure, and to fill up spaces to render walls weather tight. It is also used in concrete as a matrix for broken stones, etc., and for plastering, etc. The quality of mortar depends on the materials, treatment, proportions, and method of mixing. Fat lime should only be allowed in inferior or temporary work; mortar from fat lime is not suitable for damp situations or for thick walls. In either case it remains moist, and when placed in positions where liable to dry it becomes friable, and in any case it is weak, only a small portion of the exterior of a joint sets and mortar inside remains soft. Pressure is thrown on outer edges of bricks, and bricks chip and face of wall becomes detached, pointing has to be resorted to, and patching up in the end costs more than if good mortar had been used in first building. Hydraulic lime or cement should therefore always be used in any work of importance, especially in outer walls exposed to the weather. In work in damp, moist or watery situations, cement is absolutely necessary. Cement should also be used in all copings, corbels, plinths, arches, corners and important portions of buildings.

Sand is used in mortar to save expense and prevent shrinkage. In lime mortar, sand allows carbonic acid to act on interior parts, and particles of lime adhere to same, so that in two ways it is a source of strength; but with hydraulic lime or cement sand is a source of weakness. The sand should be sharp and clean, and the size of the grain does not materially influence strength of the mortar, and for preference coarse sand is better, unless a very thin joint is necessary. Sea sand attracts moisture, prevents a fat lime from setting, or rather drying, but is not objectionable when used with cement. All organic matters should be removed from the sand, otherwise they will putrefy and render walls and ceilings sources of unwholesome emanations. Smith's ashes and coal dust, in lieu of sand, are used to make black mortar for pointing, slating, etc. The water should be clean, free from mud, clay, or impurities, for the same reasons as given against use of dirty sand. In some cases a mortar is stronger than the building material, and you will have noticed where bricks have had hollows weathered in face when joint remains sound, so that with inferior material a strong mortar adds to strength of structure. As a rule it is more economical and better to have both materials and mortar of fair quality, with strength of equal rate. Where good lime or cement and good sand are used proportions of ingredients above ground should be: one part fat lime to three of sand, one part hydraulic lime to two of sand, one part Portland cement to from two to five parts sand in good work, or even up to eight parts sand when used in ordinary wall work. Where cement is actually in contact with water, one part of cement to one of sand should be used, and in drain joints even two of cement to one of sand is advisable. In mixing lime mortar, lime should be spread out on a wooden or stone floor, water then sprinkled on, then covered with the sand to keep in heat and moisture, so that slaking is rendered more rapid and thorough, and mixture will be ready in two to three hours. All refractory lumps should be removed which have not been slaked. When lime is purchased ready ground it is usually air slaked, and loss of energy has occurred; of course if unadulterated and fresh it is likely to be of good quality, especially where machinery is used for grinding, as only the best burnt softer clayey stones would be passed through the machines for grinding.

The great object in mixing is to thoroughly incorporate the ingredients. On extensive works a mortar mill is used, and the slaked lime is roughly turned over with the sand and shovelled into a revolving pan, and water added to bring to consistency of honey. One cubic yard of mortar is prepared in half an hour; on small works mortar is turned over by hand, but mixture must be incompletely incorporated. In mixing cement mortar the cement and sand should be mixed dry, turned over three times, and then water added. The cement mortar must be prepared fresh, and not allowed to begin setting before use. Experiments have shown that bad qualities of rich limes may be improved by adding coarse sugar dissolved in water for mixing: the proportion being from $\frac{1}{8}$ per cent., but not exceeding 2 per cent. of the amount of solid mixture. The common mortar used in the buildings in Egypt, Palestine, etc., was found to be of calcined shell mixed with clean sand and sugar, and this mortar has resisted the action of weather in some cases for centuries. In America sugar is mixed with cement in rendering of roof gutters, and in my own experience I have found that beneficial results have arisen through use of sugar mixed with cement mortar; bad lime may also be improved by adding Portland cement, and in the outer wall of the Albert Hall the following was used:—one part Portland cement, one part lime, six parts clean sand. The lime was slaked for twenty-four hours, then mixed with sand for ten minutes, then cement added, and whole ground for one minute and used.

Grout—is thin liquid mortar poured over brickwork to fill joints, and is necessary and advisable where empty joints are left in consequence of bad workmanship, but should be avoided where possible. The bricks or stones should be thoroughly soaked to prevent absorption of water from the mortar, to remove any dust, and to permit of better adhesion by the mortar; mortar should be stiff enough to spread, the joints should be well filled, and the mortar should be prepared on a platform above the ground.

Concrete—is an artificial compound of lime or cement with sand and some hard material such as broken stone, gravel, burnt clay, bricks, flag, etc. It should be thoroughly mixed and free from voids; the broken material is known as the aggregate and the cementing material as the matrix. As a rule the matrix should be better than that used in walling, as it receives less support from the broken stones than mortar does from the sand. The best manner of mixing is to mix all materials dry, and then sprinkle with water while being incorporated; too much water will wash lime or cement away. The moist mixture is then turned two or three times. The stones should be angular, as matrix adheres better, and for ordinary work stones are broken to go through a $1\frac{1}{2}$ in. to 2 in. mesh or ring. Sound bricks, coke, gravel, ballast if angular, and broken stone all make good concrete, shingle and flint are generally too round and smooth, slag from iron furnaces too glassy, but also dangerous if any lime lumps are left in same. Breeze concrete is made to receive nails. The materials are broken as a rule by hand, but stone crushers are sometimes employed, or else the mortar will become as hard as the aggregate. The object should be for concrete to contain as much broken material and as little mortar as possible. The materials in lime concrete are usually one part quicklime, two of sand, five or six broken stone. This mixture is probably used as the result of experience; but to obtain proper proportions it would be better to measure voids in aggregate by filling up interstices with water, and measuring the space filled by the water, and then prepare matrix in accordance with space required to make aggregate a solid mass.

In practice more mortar would be actually mixed to allow for imperfect mixing and waste. The voids in one cubic yard of stone, 2 in. gauge,$=10\frac{2}{3}$ cubic feet; the voids in one cubic yard of sand$=6$ cubic feet; the voids in one cubic yard of ballast$=4\frac{1}{2}$ cubic feet, so that proportions to fill voids must be regulated in consequence. Sand is a necessary ingredient where concrete is to be water proof, and is also desirable on account of strength, and experiments have proved that concrete made with sand is stronger than that without sand. Concrete is much used for paving and pavement slabs. For paving it is preferable to use a granite or harder material than the matrix, and to use very little sand in the latter. As the matrix wears away, the pebbles or stone project slightly, making the surface less slippery and at same time matrix is protected from future wear. For washing and cleansing purposes, of course the paving would be better brought to smooth surface. In Peterhead Breakwater concrete blocks were composed of one part Portland cement, six parts sand and broken stone, with blocks of granite rubble incorporated. In Metropolitan Main Drainage Works, one Portland cement, five and a half broken stone and sand, used for sewer work. In Metropolitan Drainage Work, for roofs and floors, one Portland cement, six gravel; for walls, one Portland cement, eight gravel. Fat lime is almost useless for concrete. Cement should be cooled before mixing.

Laying.—Concrete should be wheeled to the place to be laid, and gently tipped — not thrown from a height — into position and rammed in layers twelve 12 inches thick—each layer to follow the other before setting, to obtain key and avoid horizontal joints. The layers should be perfectly level so that water should not run and carry cement with it. Tipping from a height separates the heavy and light portions, and concrete is therefore not uniform throughout. Shoots are open to same objection as tipping when layers must be left to set. The surface should be swept clean, made rough by brick, and covered with thin coating of cement, as when layer is rammed, fine particles come to top, and a thin exudation preventing adherence of upper layer takes place. Quick setting cement concrete should not be rammed; concrete to be laid under water should be sent down a closed box, so that until it reaches its position, the water does not injure the mixture. Concrete blocks are made from two to two hundred tons weight, and running cranes, etc., used to plant in position.

Plastic concrete is composed of partially set ordinary concrete mixed with a little quick setting cement and is said to better resist the action of the sea. For tide work where concrete is required to set quickly, Roman or other quick setting cement would be used. Portland cement concrete should be protected under water by canvas until properly set; for fire proof floors plaster of Paris is used as a matrix in forming the concrete. To make one cubic yard of concrete composed of one Portland cement, two sand, and six parts stone, the following would be required: four and a half cubic feet of cement, nine cubic feet of sand, twenty-seven cubic feet of stone, and twenty-five gallons of water. After ramming, concrete is compressed into about nine-tenths of volume it occupies when first made.

Expansion.—Concrete, when made with unslaked hot lime or cement, expands from one-eighth to three-eighth inches per foot in lineal dimensions. In thin concrete such as paving, the area should be divided by the introduction of latter to prevent cracking; joints can then be filled with cement. In underpinning walls, hot lime concrete has been used owing to its expanding qualities tending to lift the defective work. Concrete is used for arch spandels, house walls, stairs, paving, segments of sewers, etc. Beton is concrete made with hydraulic lime or cement. Grant's experiments showed that cement concrete, one cement to six aggregate, made in block (twelve inch cube) after seven days immersion in water crushed at ninety-one tons, and when kept in air crushed at eighty tons, and he also found that broken stone formed the best aggregate to use. Tar concrete is made of broken stones and tar: twelve gallons of tar to one cubic yard of concrete. Pitch may be added; one bushel of dead lime added tends to harden mass. The materials are heated and mixed before adding the tar. Iron concrete composed of iron turnings, asphalte, bitumen and pitch are used for backing of armour plates.

Efflorescence on Walls.—Efflorescence is formed by a process known as saltpetreing. Generally it is white and crystalline, and shows chiefly in newly built walls, and is most apparent in dry weather, dampness being favourable to its formation. The cause is the action of the atmosphere on the potassium and sodium salts of the mortar and of the bricks. It will eat through paint and detach materials. Remedies in stonework and brickwork—a wash of powdered stone, sand, and water is applied and then cleaned off, and operation repeated as necessary. Painting the surface sometimes is efficacious before efflorescence begins. Animal fatty matter may be mixed with the lime mortar to the extent of about one-tenth per cent. Anti-chemicals are used when chemical efflorescence can be determined.

Plaster.—A great variety of materials are used by the plasterer, but the principal and most important are the cements already considered; plaster of Paris, Roman cement, Keene's cement have already been described. Portland cement stucco is formed of Portland cement and chalk, and is weaker than Portland cement, but not so liable to crack. Keene's and similar cements are used for best class of internal plastering, and as they set very quickly they can be painted within a few hours. They receive a very high polish, and to obtain this rubbing with grit stones is used, the pores are filled with semi-liquid neat cement, then rubbed again with snake stone and putty powder. Materials in ordinary plastering are laid on in successive coats. Lime should be well slaked and cooled. Fat lime used as surface is more absorbent and the condensation is not encouraged. Salt water and sea sand should not be used. Hair, used to enable coarse stuff to hang together, is obtained from the tanner's yard, and should be long, sound, and free from grease or dirt, separated and dried. The colour of the hair is not of much importance; but white is sometimes selected for finest work. Coarse stuff is rough mortar composed of one part lime to one or one and a half of sand, mixed with hair in proportion of one pound hair to two cubic feet of stuff in best work, or one pound hair to three cubic feet of stuff in ordinary work. The sand and lime are first mixed, the hair added and mixed with a rake; sufficient hair in the mixture will permit of the stuff hanging from trowel without falling off. Fine stuff is fine lime slaked to a paste with a small quantity of water, then diluted till of the consistency of cream and allowed to settle, the water allowed to run off, and the mass then comes thick enough for use after evaporation. A small quantity of hair is added sometimes, and in Hongkong soaked soft paper pulp.

Plasterers' putty is sieved fine stuff and is used without hair. Gauged stuff is three-quarter to four-fifths plasterers' putty and remainder plaster of Paris, and is used for finishing walls and cornices. In cornices the proportions of putty and plaster are equal. Rough cast is composed of washed gravel mixed with lime and water, and applied in a semi-fluid state. Common stucco is one part lime to three parts sand. Trowelled stucco—one-third lime to two-thirds fine stuff without hair. Bastard stucco is similar without hair. Rough stucco—more sand is used and the surface is roughened to represent stone. Artificial marbles are made with cements, and colours interspersed, and coloured silk is put in, and then extracted, leaving markings to represent veins. Enrichments: plaster of Paris put into moulds made of a composition of whiting, glue, water, oil, and resin. Papier-maché—pulp or sheets of paper to about one-quarter inch thick pressed into patterns by moulds. Fibrous plaster is formed by a thin coating of plaster of Paris on a coarse canvas backing, stretched on light frame; large surfaces can be readily covered, and it is less than one-quarter weight of plaster and can be painted at once. Dennett's fire proof material is concrete embedded in calcined plaster of Paris and is much used in theatres.

Asphaltes—are combinations of bitumen or mineral pitch and calcareous matters sometimes found in nature, and sometimes artificially formed. Natural asphalte is generally ground, mixed with sand, and run into moulds, and when thus mixed it is known as "Mastic." Coal tar pitch is brittle, easily softened, and weak. Good asphalte is waterproof, fireproof, easily applied and elastic. It is used as damp proof and for surfacing flat roofs, lining of tanks, for tennis courts in temperate climates, washhouses, and skirtings. When well spread and brought to a smooth surface it wears well in footpaths and carriage ways, but is slippery in damp weather; it is used for pointing joints to prevent penetration of wet. Good asphalte would stand 140° to 160° Fahr. without appreciable softening. The two principal methods of preparing employed are: firstly by being melted, spread and rubbed; secondly by being ground to powder and consolidated. Second method is best, and should be carried out when possible. A concrete or other solid bed should be used under asphalte; on a slope exceeding one-tenth it is apt to run. Seyssel asphalte is natural and obtained from Jura Mountains. It is boiled and applied by ladle and sanded. Val de Travers asphalte from Switzerland is laid either boiling, or as powder compressed. There are many other kinds on the market, both natural and artifical. Inferior asphaltes are made with coal tar pitch, boiled with sand and chalk. Bitumen is a mineral pitch and is much to be preferred to coal tar pitch (the residue from distilling coal tar).

WHITENING AND COLOURING—Limewhiting or limewash is pure white lime mixed with water, and is used for sanitary purposes. It should be applied with hot lime freshly mixed; one pound of tallow (free from salt) added to every bushel of lime improves the mixture. For outside work take clean water-tight barrel, put in half bushel lime, slake, cover with water to five inches deep and stir. When slaking is finished add two pounds sulphate of zinc and one pound common salt; these will prevent cracking. Common colouring is limewhiting with colour added; whiting is made with powdered chalk mixed with water and size, and used for ceilings. It will not stand weather. Distemper is the name given for all colouring mixed with water and size. When wanted very white, potato starch instead of size is used.

METALS.—The metals used by the engineer and builder are iron, copper, lead, zinc, tin, and some of their alloys. The above metals are not found to any great extent in the pure metallic state, but in the form of oxides, carbonates, or sulphides, called ores. The ores are broken up, separated from earthy matters by stamping or crushing in mills, and by washing, which carries away the lighter impurities leaving the ore which is then said to be dressed. The next step is roasting in heaps or in kilns, to drive off moisture and the carbonic acid, and to fit it for smelting.

SMELTING.—The ore is mixed with a flux selected to combine with the impurities; the mixture is then subjected to intense heat, the metal sinks to a fluid state, and the impurities combine with the flux and run off in a light and fusible slag. Smelting in former years was done by air at ordinary temperature being forced through kiln, and the result was known as cold blast iron. In the hot blast process the air is raised to 800° or 900° Fahr. and the process is more economical and now generally used; the impurities are extracted better if care is used. Limestone is used as a flux with English iron. When a considerable quantity of molten iron is in furnace, the furnace is tapped and iron runs into a long channel with branches each side. The channel iron is known as long iron, and branch iron as pig iron. In pig iron it is sold to founders and manufactures. Pig iron is made into cast iron, wrought iron, and steel. Cast iron contains 2 per cent. to 6 per cent. carbon; wrought iron contains ·25 or one-quarter per cent. carbon; steel contains one-seventh to one and eight-tenths per cent. carbon. The differences between above depend on the amount of carbon present. Cast iron is obtained by resmelting pig iron and running into moulds of shape required. In best work it is again remelted in a cupola. The patterns for casting are usually made in wood a little larger than required for the casting, and impressed into sand mould. In pipe casting the core for the pipe consists of a hollow metal tube with its surface full of holes. This is wound round with strawbands, and then the whole is covered with loam smoothed to the form of the pipe. The strength is increased if it be run with a head or upper column of metal, the pressure making pipe more free from bubbles, etc., which rise into head which then can be cut off. With a large number of pipes iron patterns would be used. Large pipes and columns are usually cast vertically, and small diameter pipes are generally cast in an inclined position. Large cylinders usually have a metal or brickwork core; the core is covered with loam, smoothed with a rotating template, and dusted with a parting mixture. The outer brick cope is also coated and metal run in, the cores are removed and casting extracted; all changes in shape of a casting should be gradual. Any sharp corners or angles are a source of weakness; the cooling should be gradually carried out.

Examination of Iron.—The edges of castings should be struck by a light hammer; if casting is good a slight impression will be made, if fragments fly off, the iron is hard and brittle. Air bubbles are common and dangerous; they should be searched for by tapping all over with a hammer. Dulness of sound will lead to their detection; the exterior should be smooth and clean, the edges should be sharp and perfect, the surface of fracture should be bluish grey of high metallic lustre. Pipes should be straight, true in section, the metal of equal thickness throughout, and proved under hydraulic pressure of four or five times the working load. Small girders are tested by weighting until they break; large castings by testing small pieces of iron cast from same metal.

Wrought Iron—is pig iron with the impurities removed by refining. Puddling consists in melting the iron, submitting to current of air and well stirring. As the carbon is removed, lumps appear; these lumps are placed under hammers, which consolidate the iron. The iron is then passed under rollers and converted into plates and bars.

Tests for Wought Iron.—Certain angles for bending should be compared with tables prepared. Rivets should double fold without fracture. Heads should stand being hammered down to one-eighth inch thick without cracking edges;

small uniform crystals or fine close silky fibres indicate a good iron. Blotches and coarse crystals are objections; the fractures examined should be of bars at least half inch thick. The fibres may be exposed by immersing specimen in nitric acid which eats away softer material leaving the fibres. The market forms of wrought iron are bar, oval, round, hexagon, etc., angle irons, channel, girder, bulb, rails, sashbars, rivet, chain, nail, plate and sheet. Plate iron is made in thicknesses one-eighth inch to one inch. The term sheet iron is usually applied to material of less thickness than No. 4 B.W.G., *i.e.* ·239 inch. Corrugated iron is made by passing sheets through rollers. Galvanized iron is iron covered with a coating of zinc. Hoop iron is usually tarred and sanded, and used as an additional bond in brickwork.

STEEL—is iron containing a small percentage of carbon, the alloy having the property of taking a temper. The difference between steel and wrought iron is as follows:—When steel is raised to red heat and suddenly cooled it becomes hard and brittle: this process known as hardening has no effect on fine wrought iron. Tempering is a characteristic distinguishing steel from cast iron. If steel has been hardened as above described, it may be softened again by applying a lower degree of heat and again cooling: this is known as tempering. Cast iron may be hardened, but not softened; a bar of steel being struck gives out sharp metallic ring. Steel is elastic and magnetic. Steel may be produced either by adding carbon to wrought iron, or removing carbon from cast iron. Blister steel is made from fine wrought iron which has been melted between layers of charcoal powder and then used for conversion by different processes to the other kinds of steel. Cast steel is used for cutlery, etc.; Bessemer steel for rails, hatchets, hammers, etc., boiler plates, members of roofs and bridges; Siemens steel largely used in shipbuilding; mild steel (two to five per cent. of carbon) for steel rails, boiler plates, etc. When more carbon is present the steel becomes hard steel.

Casehardening is a process by which surface of wrought iron is turned into steel to resist wear, and combined with internal hardness of the iron. The steel is about one-sixteenth to three-eighth inch thick. Gun locks and keys are generally case hardened. Steel may be distinguished from wrought iron by placing upon the metal a drop of diluted nitric acid (one part acid to four parts water). If the metal be steel a grey stain will be produced. Steel wire, used for pianos, and steel rope, has a tensile strength of one hundred and twenty to one hundred and fifty tons per square inch, and an elongation of 33 per cent. Heated steel by being plunged into oil instead of water is hardened and toughened.

CORROSION.—Cast iron does not rust rapidly in open air, but immersed in salt water steel is gradually softened. Wrought iron rusts more rapidly than cast iron in the open air, and is softened by salt water. Steel rusts very rapidly in open air, but the corrosion in water is less than that of wrought iron.

Preservation.—Galvanizing is preservation by covering metal with zinc, and as long as the coating is intact the iron is preserved. Galvanizing consists in steeping iron eight hours in one per cent. sulphuric acid, scouring with sand, and washing. The iron is then heated, immersod in chloride of zinc and plunged into molten zinc. Painting is an effectual preservative, if paint is good and properly applied. Oxide of iron paints should be used for iron work; bitumen paints for inside of pipes or for ironwork fixed under water. Angus Smith's process for preventing corrosion in iron pipes has been found successful. The mixture is coal tar, pitch, linseed oil, and resin, heated to 300° Fahr. and the pipes being heated to 700° Fahr., are then plunged vertically into the mixture. The heating of pipes in practice is sometimes dispensed with. The Bower-Barff process covers pipes with a coating of black magnetic oxide by aid of super-heated steam and by chemical action. Bright ironwork should be protected by a coating of tallow mixed with white lead. Bronzing does not stand weather well. Gilding has to be done with special care: the iron has to be cleaned, then painted two coats oxide paint and then two coats lead paint of light colour, or a basis of oil gold size, upon which gold leaf is placed. When properly done the gilding will last fifteen to twenty years.

Copper—is used for slating nails, bellwires, lightning conductors, dowels, wire cord, and for bolts where iron would be corroded. Copper corrodes slowly in air and gets covered with verdigris.

Lead—is used for cisterns, pipes, flat roofs, and as a basis for white lead used in paint; lead is also used for bedding girders. Soft water and organic-mattered water acts upon lead, and water is liable to be poisoned, consequently lead should not be employed for cisterns or pipes of a water supply. Impure air also corrodes lead. In England, soil pipes are made from drawn lead. An inner pipe of tin with lead casing has been found satisfactory for water piping.

Zinc—is used for roofs, gutters, cisterns, pipes, ornaments, ventilators, and as a basis for zinc paint. The metal is produced from ores known as calamine, blende or black jack, and red zinc ore, by washing, condensing, etc. It is easily corroded by moist air, and near sea air destroyed. Soot is very destructive to zinc. Good zinc is of uniform colour, tough, and easily bent without cracking. Zinc should not be allowed in contact with iron, copper, or lead, as it is destroyed by voltaic action. Zinc should be kept clean from lime and any wood containing acid, and from cats. Zinc catches fire at red heat and blazes furiously.

Tin—is used for lining lead pipes, and for small gas pipes. The metal is obtained from tin ore. It is distinguished by crackling when bent.

Brass—is an alloy of copper and zinc.

Muntz Metal—is an alloy of copper and zinc in different proportions to brass, and is used for sheathing ships.

Bronze—is a mixture of copper and tin.

Gun Metal—is a mixture of copper and tin used for pump valves.

Bell Metal—is a mixture of copper and tin for bells.

Aluminium Bronze—is a mixture of copper and aluminium.

Phosphor Bronze—is bronze with phosphorus.

Pewter—is an alloy of tin and lead, and is used for drinking cups and covering bar counters but is not recommended to be used.

Solder—is formed of alloys used for purposes of jointing metals; hard solder will fuse only at red heat, soft solder will fuse at low degrees of heat. Hard solder may be formed of copper and zinc, and the process of jointing of copper, brass, and gun metal is brazing. Silver solder is silver and copper or brass, and is used for fine Joints in iron, etc., and in mending silver articles. Soft solders may be made from tin and lead.

Timber.—The timber used for building works is obtained from trees known as "Exogens" or outward growers. In this class of tree the stem grows by deposit of successive layers under the bark, while bark becomes thicker by deposit on its under sides. These trees are formed as follows: by pith in centre, then rings, then bark. Each annual ring is darker on outside than inside. The rays from centre are known as medullary rays. If cut obliquely the rays present "silver grain" of beautiful figured patterns. The tubes convey nourishment from earth to leaves. As trees get older the inner layers are hardened and become "heartwood"; the remainder is then known as "sapwood." In the tropics some trees put on two rings in one year. The heartwood is the strongest while tree is growing, but after growth stops then first to decay; therefore the tree should be felled at right age. Trees cut too soon are full of sapwood. Directly a tree is felled it should be squared or cut into scantling, in order that air may have full access to the wood.

Characteristics of Good Timber.—The wood should be uniform with straight fibre, free from large or dead knots, flaws, shakes, or blemishes. It should smell sweet, surface should not be woolly or clog the saw, but should be firm and bright with silky lustre. A disagreeable smell betokens decay. Rings should be regular and close together; when rings are open and porous wood is weak. The timber should not become suddenly pale from heartwood to sapwood, but gradually do so. Darkness is generally a good sign of strength. Good timber is sonorous when struck; dully heavy sound betokens decay. Heavy timber is generally stronger than light timber. The sap should be entirely removed; strongest part of balk would be the rings of heartwood next to sapwood.

Defects:—Heartshakes are splits or clefts near centre, sometimes right across the balk. Starshakes formed as a star. Cupshakes open spaces between rings. Rind galls are curved swellings caused by bark growing over a wound where branch has been improperly lopped off. Foxiness is a red or yellowish tinge caused by decay. Doatiness is a speckled stain. Twisted fibres are caused by prevalent wind turning the tree constantly in one direction, and tree thus injured is not fit for squaring. Fir wood contains turpentine, has straight fibre, and from its regularity in growth is useful for planking. Hardwood contains no turpentine; woods with decided medullary rays are liable to warp. Soft woods include firs, pine, spruce, larch and all cone bearing trees. Hardwoods include oak, ash, beech, elm, mahogany, etc. Pine has close grain, is fibrous, durable and bright. Fir is light and durable.

FORMS OF TIMBER:—A log is a trunk of tree; a balk is a squared log; spars or poles are twenty-four inches diameter; planks are two-sixths inch thick, eleven inches wide, and eight feet to twenty-one feet long; deals are four inches thick, nine inches wide; waney timber is timber not perfectly square, the rounded part of tree remaining at corners after log is cut into timber. Pine is used for all building purposes and for floors. American red pine is used for fittings and veneering. Pitch pine is used in heavy timber structures and for durable floors, sills, and ornamental work; white fir for joinery, floor boards, panels, and it should not be less than one inch in thickness. Cedar for doors, windows, joinery and veneering. The pungent odour of cedar tends to keep out insects. Oregon pine for joists and masts. Kauri pine is only found in New Zealand. It is fine, white and straight, with agreeable odour, and not likely to shrink. It is used for masts and spars, military bridges and joinery.

HARDWOOD.—Oak. The heart of oak has been found durable after one thousand years, and in water oak is very durable. Oak is liable to attacks of insects, it contains gallic acid and corrodes iron fastenings. It is used where great durability is required, such as in windows and door sills, treads of steps, wedges, joinery, gateposts, etc. Wainscot is a species of oak, soft, not liable to warp or split and highly figured. Beech is used for piles under water, mallets, planes, cabinet work, and chairs; mahogany for handrails, joinery and cabinet work, and as substitute for oak. Jarrah is from West Australia, and is used for piers, jetties, piles and shipbuilding, and when sound not attacked by waterworm. Teak is found in India, Burma, Java, etc. The lightest and cleanest comes from Burma, the heaviest from Johore. It has fine straight grain something like the English oak in appearance, but no visible medullary rays. It varies from brownish-yellow to dark-brown. It is light and easily worked, contains resinous oil which makes it durable, and enables it to resist white ants and worms to some extent. It is used for backing armour plates, as it protects iron from rusting; also in shipbuilding, floors and house joinery (generally of best class), and furniture. "Butchai" is a wood used in Hongkong for timber roofing, frames, girders, and all hardwood requirements. It is of light colour with fine grain. "Hungchap" is coarse grained and not so good. "San Cheong," or Chinese red wood, is good for joists, floors and frames. Singapore wood is very poor, open grained, and useless where exposed to weather. Camphor wood is used in boxes, and is now being introduced into general framing.

In the selection of timber one would be guided by studying the characteristics of good timber before mentioned. Seasoning is either to expel, or to dry up the sap, which otherwise decays. The timber is reduced in weight by seasoning, and this to some extent indicates success of process employed. Timber should be well seasoned and left to thoroughly season before painting. Natural seasoning is carried out by stacking timber so that air can circulate round each piece, and at same time protecting timber from rain, sun, draughts and high winds. Water seasoning is done by putting timber under water and chaining down for about a fortnight after cutting to wash out sap, then carefully dried. Care must be taken that the timber is wholly submerged. Salt water makes timber harder, heavier and, more durable, but should not be used for building timber, as it always attracts and retains moisture. Hot air seasoning or desiccation is effected by exposing timber in hot oven, and drying out sap. McNeile's process exposes wood to moderate heat in moist atmosphere to various gases. In smoke drying, timber is smoke dried over a fire of furze, straw, or shavings, and heat applied gradually. Floor boards should be stacked before laying; door sashes and joinery should be left as long as possible before wedging up.

PRESERVATION.—Wood should be kept free from dampness and free from contact with mortar, also from alternate wet and dry situations. The want of ventilation hastens decay; dry rot is caused by want of ventilation. This encourages growth of a fungus which eats into the timber. It generally commences in the sapwood and reduces same to powder. The ends of timber should be protected by iron, zinc, or lead where entering walls; oil cloth induces dry rot in floors for same reason. Painting and tarring unseasoned timber has same effect. Wet rot occurs in the growing tree, and where timber may become saturated with rain, but seasoning will partly cure wet rot.

DETECTION OF DRY ROT:—Bore into timber with an augur or gimlet, and examine and smell dust extracted. Strike timber with key on one end and sound is heard distincly at other end if good wood, but dull and faint sound will be heard or none at all if timber is decayed. Strike with hammer and judge by sounds. Painting preserves if wood is seasoned, otherwise painting had better be omitted; same may be said of tarring. Charring of ends is done with a view to preventing dry rot and attacks by worms. The timber must be seasoned before charring; railway sleepers, gate posts, and timber going into earth should be charred and tarred. Creosoting is effected by extracting moisture and air from the tubes of timber and forcing in oil of tar (generally called creosote) at a temperature of 120° Fahr. under a pressure of one hundred and seventy pounds per square inch. Fir timber will take ten to twelve pounds of creosote per cubic foot. Oak and hardwood will take two to three pounds. To soft wood an imperfect creosoting may be applied by drying timber over fire and placing while warm in hot creosote. Creosoting is the most successful preservative process known. It destroys insects and worms, excludes moisture, and prevents dry rot, and even protects against the white ant. There are many other processes by which chemicals are forced into the pores of timber. Sir William Burnett's system consists in steeping timber in a solution of one pound chloride of zinc to four gallons of water, and process is known as burnettizing.

Preservation from Fire.—Burnettized timber is preserved somewhat from action of fire ; cyanite is a fireproof solution which has proved successful. Asbestos paint affords slight protection. Worms in salt water (the "Teredo") are most destructive to timber, and prefer clean water to muddy. Driving broad headed scupper nails, sheathing, and creosoting are methods used to prevent damages by "Teredo." White ants are cream coloured, about one-quarter inch long, with black head. It grows wings at last stage of existence and dies ; no timber thoroughly resists them. Creosoting with bone oil is the best remedy, but the smell is bad. Kerosine is effective while smell lasts. Arsenic has been found to be ineffectual.

Paints and Varnishes.—The materials in point are: bases of white lead, red lead, zinc oxide, iron oxide. Vehicles: water, oils and spirits of turpentine. Solvents: spirits of turpentine. Driers, litharge, sulphate of zinc, red lead, etc., colouring pigments, ochre, lampblack, sienna, etc. White lead is made by treating ordinary lead to acid fumes, and removing the crust formed. It is best protection for wood, and permanent. Red lead is produced by raising oxide of lead to high temperature. Red lead is used for driers, for painting iron, and priming wood, Oxide of zinc is basis of zinc paint and has no smell, so that a room may be occupied directly the paint is dry. Oxide of iron is produced from brown hematite ore, roasted and ground.

Oils.—Linseed oil (produced by pressing flax seed) is most commonly used, and is best of all oils for paint, putty, etc. It dries better and has more tenacity and body than other oils. Raw oil is used for internal work and is light in colour. Boiled oil is used for external work and is dark in colour. I should not recommend any other oil to be used. Driers are added to make paint dry quickly, and should be used with caution, and should not be added until colour is ready for use. White lead paint, if used fine, often induces painters' colic, and action of air gives it a brown shade. By entering pores of the skin, lead poison causes paralysis. Many special paints have been invented, and are on the market already mixed. Enamel paint is hard and washable ; cork paint has a matrix of granulated cork ; luminous paint has a phosphorescent glow.

Tar Paint :—Coal tar nine gallons, slaked lime thirteen pounds, turpentine two or three quarts, sprinkled with sand, where exposed to weather, was successfully used for the canvas roofs over the tubes of the Britannia Bridge.

ORDINARY TARRING.—Boil six gallons coal tar with one pound resin, one pound pitch, and apply hot; or use Stockholm tar with pitch only.

VARNISH—is a solution of resin in oil, turps, or alcohol. It is used to give brilliancy to painted surfaces, and to protect from action of atmosphere and friction, and also to intensify the grain of woods. The best known varnish is Copal, which has for its base gum copal. This gum exudes from trees in East and West Indies. Copal varnish becomes lighter by exposure. Amber is also used as a gum in varnish, and is found between beds of wood coal, or thrown up by storms on the coasts of the Baltic. It is then dissolved, but is costly and slow in drying.

FRENCH POLISH.—The simplest is one and a half pounds of shellac to one gallon spirits of wine. It is applied by rubbing to surface of the wood.

JAPANNING—consists of applying successive coats of oil paint mixed with varnish, and each coat is then dried at a high temperature. It may be used for baths. Stains are liquid preparations applied to unpainted surfaces of ordinary woods to give appearance of the more rare and highly coloured woods, such as rosewood, mahogany, etc. A wash for removing paint: two ounces soft soap, four ounces potash in boiling water, half pound quicklime. Apply hot, leave for twenty-four hours, then wash off. This is quicker and cleaner than burning or scraping.

GLASS.—Sheet glass is used for pictures, and first-class glazing. Fluted glass of many sections used where privacy is required. Patent plate is made by polishing sheet glass. British plate glass is made by pouring white glass on to iron table and rolling under heavy metal roller, and is much used for shop windows. Rough rolled plate is fluted one side, and is suitable for conservatories, skylights, and roofs. Cathedral glass is used in ecclesiastical work. Ground glass is obscured by grinding surface or pouring melted glass on same. Embossed glass has patterns eaten out by acids. Coloured glass is made of every tint for decorative purposes. Glass tiles are made for roofing.

INTERCEPTION OF LIGHT.—British polished plate intercepts 13 per cent. of light. Rough cast plate, one not dull, intercepts 30 per cent. of light. Rough cast fluted, 53 per cent. of light. Sheet glass, thirty-two ounces to a foot, 22 per cent.

PAPERHANGING.—Pattern is usually printed from wood blocks, but some papers are coloured by hand. English papers are usually twelve yards long by twenty-one inches wide. Lining paper is placed under better kinds. Papers containing green are as a rule objectionable, as they are often coloured with arsenic, mercury, copper, and other deleterious substances. These fly off as dust and may poison the occupants of a room in which paper is hung. Other colours are equally as harmful.

LINCRUSTA WALTON—is a mixture of boiled linseed oil with dried fibre, which is subjected to pressure and designs are formed in relief. It can be washed or scrubbed, is very durable, and a non-conductor of heat. Damp walls should be covered with water-proof material before hanging paper. Washable paperhangings are made, suitable for hospitals, etc. Papers on a wall are ornamental, and give a room a bright and cheerful appearance. Plain white paper may be applied with advantage where ceilings are inclined to crack.

Miscellaneous.—Glue is prepared from waste pieces of horns, hoofs, skins, and other animal matters. When freshly made, glue is stronger. Size is melted glue thinned by adding water. Double size is double strength. Clear Cole is a coating of size put on wood to prepare for coat of varnish. Knotting is material to cover knots and sometimes silver leaf is used. Paste is required by paperhangers. Gold leaf for gilding. Putty is whiting and oil. Laths are long strips of wood used by plasteres. Tar is produced by heating coal, and is a bye product in gas manufacture, and when itself distilled produces naptha, creosote, and pitch. Wood tar is produced by distillation of fine and resinous trees. Mineral tar is a natural tar found in Burma. Felt is generally saturated with bitumen and is used for roofing, dampcourse, lining damp walls, lining iron houses, slate roofs, and under floors to deaden sound, and for bedding columns and girders, also for preventing escape of heat from boilers and pipes. Asbestos is a fireproof and acidproof mineral. Wire wove roofing is a preparation of linseed oil on fine wire mesh, and is semi-transparent. Expanded metal is used for partitions, ceilings, columns, etc. Silicate of cotton or slag wool is a glass-like fibre blown from blast furnaces. It is incombustible, vermin proof and very light. One ton covers 1,800 sq. ft., 1 in. thick, and makes floors and ceilings sound and fire proof. There are three hundred varieties of nails used for all purposes. Screws of all kinds and materials are used in building.

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SOILS

By B. BROTHERTON HARKER, A.M.I.C.E.

INCOMPRESSIBLE SOILS.

Rock.—Solid rock under the whole of the building affords a first rate foundation, if it is perfectly uniform in character, thick enough to bear the weight safely, with an upper bed approximately horizontal or perpendicular to the pressure upon it, and not liable to be affected by atmospheric influences. In such a case it will be necessary only to break down projecting points, cut away loose rotten parts, making good and carefully filling in all cavities. If the strata are inclined there is danger of the upper layers sliding over the lower. If a rock is of a nature to disintegrate when exposed to weather, it should be protected by concrete.

Stony Earth.—Soil consisting partly of hard rock and partly of soft ground such as clay, earth, or sand, is most dangerous and untrustworthy, as the latter will yield more than the former, causing unequal settlement. If the softer parts are of small extent they may be arched over, using the adjacent portions of rock as abutments. If this is not possible they should be consolidated by driving in piles close together, or excavating to a good depth and filling in with concrete. If neither of these expedients can be adopted, the building over the soft parts should first be carried up and allowed to settle to its bearings, and then the remainder built upon the hard rock, the latter being kept distinct from the former.

Gravel—when sound, makes one of the best possible foundations, as it is incompressible, and not affected by atmospheric influences. If loose and coarse it may be greatly improved by grouting it with thin mortar, or sometimes a thin layer of concrete is spread on the bottom of the trench. If gravel is very unsound it must be prevented from slipping laterally by sheet piling.

Chalk—varies immensely in its nature and characteristics: sometimes it is found as hard as rock, in other cases as soft as butter. The hardest description of chalk may be treated as rock if its permanent dryness can be ensured. The softness of chalk is caused by wet; before using it as a foundation all water should be removed and prevented from recurring. This may be done by draining the trench, punning the sides with clay to prevent the ingress of water, or by putting in concrete in weak points. Springs should, however, rather be diverted than dammed out, as otherwise they will very likely burst through in rainy weather.

CLAY—is a good soil to build upon when it is sound, tolerably dry, and protected from the action of the atmosphere by making the foundations deep, or covering the bottom of the trenches with concrete. Clay is very liable, especially in hot weather, to crack and form deep fissures, by which water is led below the surface which will injure the footings, unless they are placed deep enough to be out of the reach of the fissures, and well drained. When these precautions are neglected the clay undergoes continual changes in bulk, from atmospheric influence, which causes it to expand and contract, and then it becomes a very dangerous material to build upon, often causing very alarming settlements in a building. The best remedy against this inconvenience is to tie the walls together by means of chain plates, buried in the centre of the footings; these plates to be, of course, connected at the returning angles, so as to encompass the whole building.

SOILS REQUIRING LATERAL CONFINEMENT.

SAND—forms a capital foundation to build upon as long as it is prevented from escaping laterally by sheet piling or other means.

QUICKSAND AND SILT.—The same remark applies to these, which are the most treacherous of all soils, and will, unless such precautions are taken, yield or slip under the slightest weight. In these soils, as also in very loose gravel, care must be taken to exclude water, which might otherwise penetrate and wash away the soil, causing hollows in the foundation and subsidence in the superstructure.

COMPRESSIBLE SOILS.—Foundations in these soils require great care, more especially if the site is made up of different kinds, one more compressible than the other; in such a case unequal settlement may be apprehended, and should be guarded against.

ORDINARY EARTH OR SOFT CLAY.—In these it will be sufficient to dig a trench considerably wider than the thickness of the wall and deep enough to be below the action of frost, and to fill it with concrete. The pressure is thus distributed by the concrete bed over a larger area, and does not bear so heavily on each superficial foot of the soil.

VERY SOFT SOILS.—When the ground is marshy, or of such a nature that it would not bear the weight required, even when distributed over a large area of concrete, more complicated arrangements must be adopted, such as piling or sinking shafts of brickwork, or iron cylinders filled with concrete, or even concrete pillars encased in wood. Peat and heavy clay shrink about one-fifth their bulk in drying and swell again in wet weather, so that a building resting on such a foundation is liable to serious injury, if not carried below the reach of atmospheric changes. In such ground it is essential that the drains for the subsoil water should be laid before the work is commenced.

Made Ground—is the worst possible for a foundation, and great care must be exercised in ascertaining the depth to which the filling in goes, and on what it rests; also the nature of the material with which the cavity has been filled, as in many cases it will be found to contain all descriptions of animal and vegetable refuse in a state of decomposition, rendering the site most unhealthy for buildings to be used as habitations.

SOILS MET WITH IN FOUNDATIONS IN HONGKONG.

Granite—as you have already been informed is composed of quartz, orthoclase (potash felspar), and mica, and is found in every part of the colony, but mostly in a decomposed state near the surface, with boulders dispersed throughout the upper stratum. These boulders, when exposed to atmospheric influences, become decomposed, creating the red earth which one sees on all sides. This soil when compact and in horizontal layers forms one of the best foundations, and is easily drained, for as a rule you will find the springs confined to small areas.

Syenite—is somewhat similar in composition to granite; it contains felspar and hornblende, differing from granite in the absence of free silica (or quartz). What I have just remarked with regard to granite also applies to this rock, with the exception that it takes longer to decompose, being harder in composition.

Clay.—There is sometimes found interspersed in these soils a thin layer of clay (silicate of alumina), which is derived mainly from the decomposition of felspar, which, when exposed to the action of the weather, becomes very plastic, and if the stratum dips is liable to cause the soil to slip from under the foundations. These streaks of clay are invariably the cause of landslips here: the rain not being able to penetrate this impervious layer, collects in the upper portion of the soil until it is over saturated, causing it to slide on the line of least resistance.

Basalt—is a dense basis lava, and consists of phagioclase, felspar and augite, combined with certain metallic oxides, and shows a finely grained or semicrystalline texture in a glassy base. This rock is met with in the New Territory, and it forms a good foundation as long as the columnar structure is horizontal to the pressure placed on it. It has the disadvantages of liability to disintegrate when exposed to the action of the weather, and if surrounded by impervious strata is often difficult and therefore costly to drain.

Made Ground.—The reclaiming of the foreshore of the City of Victoria by filling in to the present levels has been a very great undertaking successfully carried out. In the preliminary surveys, soundings and borings were made to ascertain the nature of the substrata, and the depth at which solid ground was encountered, so that it is an easy matter to find out what class of soil one is likely to encounter for one's building at any point along the Praya. The filling in has been made with earth excavated from the neighbouring hills, so that very little vegetable matter has been deposited, and consequently little to fear from vegetable decomposition.

SUBSOIL DRAINAGE.

The principal source of moisture in the soil is rain, and it is only when in excess, so as to become stagnant by retention within a foot or two of the surface, that it becomes injurious. The greatest difficulty with which an architect has to contend in the ground works of a building is that of ground water in low lying lands. Springs on hillsides are easily dealt with; but the water which percolates through mud and gravel only a few feet below the surface of the ground, and rises and falls perhaps with the rise and fall of a neighbouring river or ditch, furnishes a more difficult problem. Nor is a site like this confined to plains: it may be found on the banks of most rivers, even in deep and narrow valleys. The necessity for artificial drainage does not so much depend on the rainfall, or the power of the sun to carry the moisture off by evaporation, as upon the nature of the subsoil. If the subsoil is composed of sand or gravel, or of other porous earth, the greater part passes off by natural drainage below the surface, and they are therefore dryer and warmer than clay on account of their porosity, water rapidly sinks through them, and they contain a considerable volume of air. In these the fluctuations of ground water and consequent exhalations of more or less impure ground air are more to be feared than dampness. If, however, the subsoil be of clay, rock, or other impervious substances, the downward flow of the water is arrested, and it sometimes shows its presence in the form of springs. Clays require very careful treatment on account of their retentive character, and capabilities of expansion and absorption. Subsoil drainage makes them permeable, though when the surface is not properly and deeply cultivated their capabilities of absorption are limited, and those of retention and expansion cause them to resist the admission of the rainfall. The retentive nature of clay soils can only be restrained by complete aeration. The drains should exert a powerful influence on the intermediate mass of soil, so as to secure a quick and uniform passage through it of the superabundant water. Clay is capable of absorbing from 40 to 70 per cent. of its own weight of water. The level of ground water is always raised by capillarity; the amount of rise has been estimated at about one foot in sands, and four or five feet in clay and compact marl.

In the Arrangement of Drains—it is necessary, in the first place, to ascertain the source of injurious water, so as to secure a permanent and effective discharge. To do this the geological formation and dip of the strata should be considered. Test holes should be excavated to ascertain at what depth below the surface the water will lie in wet seasons. The size of the mains should be calculated to carry away readily the water to be collected from minor drains. In each case proper allowance should be made for the inclination of the pipes.

The Depth of the Drains—should be as great as possible, and never less than three or four feet below the surface of the ground. It is desirable in some cases to lay drains under foundations, in addition to the ordinary subsoil drainage, to guard against water from below rising into them. Such drains should be laid with a considerable fall into the adjacent subsoil drains, or the water in them should be carried away from the site by an independent drain; they should not form any part of the main system of drainage of the site, so that in case of any stoppage of a drain underneath the foundations no water could find its way under the building from surrounding drainage.

Fall Given to Drains.—When the general surface of the ground is nearly level very little fall need be given to the drains. When practicable it is well to have a fall of not less than 1 in 100; more is preferable, but as little as 1 in 400 is sufficient if the drains be carefully formed. It will, however, be usually found less expensive to make a fall of 1 in 200 rather than 1 in 400, as the latter requires extra care in forming it. A very steep slope is objectionable, as the flow of water tends to injure or obstruct the drains. The fall should be uniform or of increasing descent towards the outfall, to avoid deposit of silt, as particles which would be carried along the pipes at a good fall might be deposited when the flow of water is lessened, owing to the reduction of fall in the drain. Where an alteration of fall must be made a silt basin should be placed to catch the deposit.

Distance Between Drains.—Under similar conditions the distance apart should be in inverse proportion to the rainfall, so that the maximum amount may be freely absorbed and discharged at all times. It may be made to depend upon the depth of the drains in free soils, but clay must be considered independently; the maximum distance in stiff clay should be from 3 to 4 yds., in loamy clay 5 or 6 yds., while in sand and gravel 10 or 15 yds. apart. In the latter case it will be sufficient to carry a drain around the outside of a building.

Direction of Subsoil Drains.—The minor drains should follow the line of greatest descent, and should discharge into the street mains in towns provided with the separate system of drainage; or if taken into sewers of the combined system, should be disconnected by means of a syphon trap. A convenient place for the trap is inside of an inspection chamber. In the country the subsoil drains may be carried to the nearest stream; or if there is sufficient fall, brought to the surface of the ground at some distance from the house and used for irrigation purposes.

Execution.—All works of drainage must be laid out with great care, and executed completely and efficiently. Any defects are likely to be productive of serious consequences, and are usually difficult to remedy, The consideration of the means of getting rid of subsoil water before putting weight upon the ground is very frequently neglected, the result being damp walls, unequal settlements as shown by cracks in a building, and sometimes sliding of enbankments.

Trenches—are usually from 3 to 6 ft. deep, and are cut as narrow as possible for the depth. The tops will be from 1 to 2 ft. wide, and the sides sloping. The bottoms must be carefully trimmed to the true inclination, every part being tested by boring rods. The trench should be filled in soon after the pipes are laid, and the pipes packed around by pieces of stone, fine earth, clay, or cinders—the clay in a short time becoming porous. The object of the layer of clay is to prevent the water from flowing vertically down the trench, so that it may only enter the drains from the underside, and thus avoid the deposit of silt in them.

Pipes.—The pipes in general use for subsoil drains are circular, though several other shapes are manufactured. They are made of clay similar to that used for making bricks, and are usually from 2 to 6 in. in diameter with collar or ordinary socket joints, and in some cases, where pipes of small diameter are used, they are laid simply abutting. All pipes should be laid resting firmly on the bottom of the trench, so that the filling in of the earth may not disturb the joint.

FOUNDATIONS.

It is impossible to lay down general rules for the safe bearing power of the different kinds of ground. Each site must be judged by itself; but speaking roughly, it may be said that alluvial soil, or quicksand, ought not to be loaded with more than about 10 cwt. per square foot.

Soft clay near surface..................	10 to 15	cwt. per square foot.
Moist clay	15 to 30	do.
Compact clay nearly dry...............	30 to 50	do.
Dry compact clay of considerable thickness	50 to 100	do.
Loose sand	20 to 30	do.
Compact sand, gravel and sand......	40 to 60	do.
Gravel and sand dry and prevented from slipping	80 to 100	do.

In designing foundations the great point to be observed is to so arrange them that the pressure on the ground is equal throughout. Unequal loading gives rise to unequal settlement, and probably cracks. A width of six inches should be given on each side of the footings to give the bricklayers room to work. Of course in concrete foundations no allowance need be made.

CHARACTERISTICS OF GOOD FOUNDATIONS.

A good foundation should fulfil the following conditions:

(1) It must either be incompressible, or at least equally yielding throughout.

(2) It should be perpendicular to the pressure upon it.

(3) It should be of sufficient area to bear that pressure.

(4) It should be unalterable in nature, either by atmospheric or any other influences that it may be subjected to.

Preliminary Operations.—Before commencing a building, trial pits should be dug or borings made at different points on the site, in order to ascertain the nature of the ground, the thickness and inclination or dip of strata, to find out whether water exists, and if so at what level. If there are any springs on the site their source should be ascertained and water diverted. Trenches must be dug to the widths and depths necessary, the bottoms carefully examined, sounded with a crowbar to ascertain any local defects, and then levelled throughout in one plane if convenient, if not, in horizontal benches or terraces. Trenches formed in loose gravel are apt to slip, and consequently the sides must be shored up by one or other of the following methods. In tolerably good ground poling boards, in size about 9 in. by 2 in., are placed at intervals in pairs on each side of the trench, and strutted apart by stout members: small pieces of scaffoid poles, from 4 to 6 in. in diameter, being generally sufficient for the purpose. But where the ground is looser the poling boards must be placed close together perpendicularly with wallings which are placed horizontally inside them, and strutted from one to the other at intervals of every 2 to 4 ft., the poling boards in this case varying from 1½ to 3 in. thick, and the wallings being usually 11 in. by 3 in. In running sand it will be obvious that it is impossible to wait until a sufficient depth has been dug out to allow of vertical poling boards being used without the sides previously slipping in, therefore sheeting is used, laid longitudinally and secured by poling boards, and strutted. When running sand or very soft clay has to be kept out, straw or shavings may in some cases be rammed in behind the poling boards. It is often difficult or dangerous, sometimes quite impossible, to withdraw all the timber used in an excavation; in such cases all projecting ends must be cut off below the level of the ground. No excavation except in rock or chalk is supposed to stand vertically, and unless it is to be strutted the sides should be sloped: 3 in. for every foot of height will be enough to allow.

In general terms we may direct the depth of foundations to be one-sixth part the height of the building, and the thickness of the walls twice that of those that are raised upon them. If possible the solid ground should always be reached; and if there are great variations, etc., arches should be thrown over weak places, when at a great depth from piers built on solid ground. If a solid stratum be reached, with an inferior one below, it is inadvisable to go any deeper, if that solid stratum is sufficiently strong to carry the weight required.

In Alluvial Soils—there is frequently a layer of clay over a stratum of soft mud; in such a case piles would do harm, as they would disturb and injure the crust of clay. It would be better therefore merely to pun and consolidate the clay with a rammer. The upper crust should be sounded by striking it with a log; experience will tell whether it gives out a clear ring or a hollow sound. In the latter case it is not to be trusted.

In Soft Stratum of Moderate Depth—overlaying hard ground, the foundations should be carried down to solid ground, or a number of piers may be sunk and arches turned from one to the other, or similar piers may be used to support a timber platform; or instead of piers holes may be made and filled with concrete, sand, stones or other incompressible material. Or again piles may be driven into the hard stratum to act as supports for a platform. Where from columns or small piers pressing upon particular parts there would be a liability from uneven bearing to partial failure, it has been the practice from an early period to turn inverted arches to catch on their springing the weight to be provided against, by which means such weight is equally distributed throughout the length of the foundation.

Foundations in Ground Soft to an Indefinite Depth—may be treated in several ways. (1) A wide trench filled with concrete of sufficient thickness to resist fracture will answer by distributing the pressure over such a large area that the soil is able to bear it. (2) By forming a raft of timber or fascines which floats upon the nearly liquid soil, and distributes the weight of the building over a large area. In such a case it is important that the centre of gravity of the building should be immediately over that of the platform, and the latter should be evenly weighted, or it may sink more on one side than on the other. A timber platform is constructed by placing short lengths of timber across the foundations; these are tied longitudinally by long planks laid to a width of the bottom course of masonry. A fascine platform consists simply of two or three courses formed of fascines (long bundles of brushwood) laid close together, the alternate courses being in opposite directions, and the whole being kept in position by wooden pickets. Such platforms should either be at a depth where they would be constantly wet, or be so drained as to be permanently dry, or otherwise the material will soon perish. (3) A soft soil may be consolidated by driving into it, over an area larger than the proposed building, short piles quite close together, and on the heads of these piles may be formed a platform of wood or a layer of concrete. To prevent the soil spreading laterally sheet piling may be driven. In India where there is a soil locally called the "black cotton soil" which is very soft, often of considerable depth, and containing much moisture (as much as one-eighth to one-tenth of its weight), the area is excavated to a depth of ten feet and slightly wider than the area to be built upon, and is then filled in with either sand, engine cinders, or gravel, to a height of five feet, and then two or three feet of concrete, upon which is placed the masonry.

Concrete Foundations.—Concrete is eminently adapted for use in positions where great resistance to compression is required. It is inexpensive as compared with other building materials, of equal strength and durability, and is capable of being made by local unskilled labour from any suitable material to hand. The strength of concrete varies within considerable limits, according to the quality and relative quantities of the aggregate and cementitious material employed. It is often thought that the stress which is put upon foundations is simply a compressive one; but this is not the case. There is more or less of a transverse stress, caused by the weight of the wall acting upon the central portion of the foundation, and tending to crack it longitudinally. To minimise this stress the lower portion of the wall is spread out gradually almost to the breadth of the foundation proper. The compressive strength of concrete is about eight times greater than its tensional strength. The safe load for ordinary concrete composed of one part of lime or cement to six parts of aggregate is approximately:

Greystone lime	concrete	1 to 2	tons per square foot.
Blue lias lime	do.	2 to 3	do.
Portland cement	do.	6 to 8	do.

Concrete should not be thrown in from a height, as the larger and heavier portions thereby become separated from the remainder of the falling materials, and the finished concrete is uneven in composition and strength. After mixing, it should be rapidly wheeled to the site, carefully lowered into position, spread in layers, and well and evenly rammed. Lime concrete may be left for a short time before being used to ensure the slaking of the lime. Concrete should not be built upon until it has been allowed to set for at least seven days.

The quality of concrete is largely dependent upon the nature of the aggregate. Pit gravel, shingle, Thames or river ballast, broken bricks, stone, granite, slag, furnace clincker, coke breeze and pumice are used. Sufficient sand or other suitable material, such as decomposed granite or red earth, must be added so as to properly fill the interstices and produce a compact mass, when the whole is bound together by the lime or cement (generally two parts of sand or red earth to one of lime or cement). The water should be perfectly clean and free from organic impurities. The average amount required for each cubic yard of concrete is from 21 to 24 gallons. The mixing is one of the most important operations connected with concrete. The material, properly gauged, requires twice mixing in a dry state for due incorporation, and should be ridged around a central cavity prepared to receive the water. This should be applied from a watering can with a rose, and the ingredients should be turned over under the spray, so that each shovelful receives a due proportion of water.

Concrete foundations, especially when supported on piers, cylinders, or piles, may be considerably strengthened by embedding small rolled iron or steel joists within them. Sometimes the whole site of a building is covered with concrete. The least thickness is nine inches, but a thickness of twelve inches is more usual. Frequently, however, an additional thickness of concrete is put under the wall. Concrete caissons or walls have been used on many occasions for works in the sea and marshy grounds. They consist of concrete cylinders, either circular or rectangular, in sections from 2 to 10 ft. in width, and from 6 to 24 in. in thickness; built up in sections of about 2 ft. 6 in. to 4 ft. in height, the sections being lowered into position by excavating inside, or when the water becomes too strong, by means of grabs.

PILES AND PILE FOUNDATIONS.—The nature of the ground, the thickness of the various layers or small strata, and the depth of the firm ground ultimately arrived at, are the points to which attention should principally be directed in getting in pile foundations. There are two methods of piling generally used. The one and the more ancient consists in simply forcing down timber piles by repeated blows of an iron block called a "monkey"; the other which is but of recent origin, consists in screwing iron piles into the earth by imparting a rotary motion to them by means of levers. Timber piles may be made of elm, arch, fir, beech, oak, teak, yacal, betis, malasaguin, dayandan, and other hard woods. The straightest framed timber should be selected, the bark removed, and any rough projections smoothed off; all large knots should be avoided, and diagonal knots especially are a source of danger, as a pile is very likely to be broken off at the point where they occur. Piles should, if possible, be of whole timber, and driven with the butt or natural lower end downwards. The head of the pile should be bound round with a wrought iron hoop to prevent it splitting when driven. The lower end should be pointed, and if it is to encounter stony or hard ground, should be shod with iron. Bearing piles are driven down either until they reach a hard stratum, or until the friction on their sides prevents them from sinking, upon which they are used as pillars to support a platform of timber. Such piles, if of wood, should be whole timbers from 9 to 18 in. in diameter, and if they are in soft soil their length should never be more than about twenty times their diameter, or there will be danger of their bending when driven.

SHORT PILES—are driven into soft soil to compress and consolidate it. Upon their heads may be placed a platform of timber or layer of clay or concrete. These piles are only from 6 to 12 ft. long, of round timber about 6 in diameter. They should be driven as close together as is possible without the driving of one pile causing the others to rise. To prevent this it is found necessary to place them at intervals of about 2 ft. 6 in. from centre to centre.

SHEETING PILES—are used to enclose the areas of a foundation, and thus prevent the soil from spreading laterally, or to protect it from the action of water. In using sheet piling to enclose soft ground, long "guide piles" about 6 to 10 ft. apart are first driven in the direction required. After the piles are driven, and their heads sawn off level, a timber platform is generally laid on them. This consists of heavy square balks, called string pieces and cross pieces, notched into one another so as to form a grating or grillage.

CAST IRON PILES—have been used of various cross sections, such as square, round, hollow and cross shaped. In driving them a block of wood, called a "dolly," must be interposed between them and the "monkey," for fear of breaking the pile by the sudden shock.

Screw Piles.—In these the pile itself may be of timber, or a cylinder of cast or wrought iron. It is furnished at the lower end with a short and broad cast-iron screw blade, which is twisted round under pressure so that it enters the ground, from which a great force would be required to withdraw it. According to the best authorities the test of a pile having been sufficiently driven is that it shall not be driven more than one-fifth of an inch by thirty blows of a ram weighing 800 lbs. and falling five feet at each blow. The safe load on piles driven into solid ground is 1,000 lbs. per square inch of area of head; on piles driven into soft ground by friction on their sides, 200 lbs. per square inch of area of head.

Tubular Foundations.—These are generally composed of cast iron tubes of large diameter, united in lengths by internal flanges and bolts. These cylinders are sunk by excavating the earth from within and under them in various ways. The water may be kept out of them by pumping in compressed air. The excavation can then be done by men working within the cylinder, or if water is not forced out, the excavation may be carried on by special excavating machines lowered from above, such as a grab. In cases where the soil is very soft, cylinders have been sunk by exhausting the air from within them, so that they are forced down by the atmospheric pressure acting upon their covers or upper surface. It is better to sink one large cylinder than several small ones as they are apt to jamb one another.

In all buildings with cellars it is an object to have a second thin wall outside the basement walls, so as to leave between it and them a cavity for the circulation of the air: such cavity is called an air drain. This, in all cases, is necessary, but in moist and loose soils essentially so. It is important that the air drain or dry area should communicate with the external air by means of ventilators placed in the upper portion. To prevent moisture from the ground rising in the walls, a damp proof course formed of either asphalt, cement, slate or lead is placed about 6 in. above the points of contact with the surrounding soil. Foundations made in countries subject to earthquakes have as yet to be perfected; many experiments have been made to counterbalance the action of seismic waves on buildings, such as building in tension rods in the foundations and uniting them with a network of iron throughout the building. Also by constructing the superstructure so as to have the principle weights to rest on pillars of stone resting on iron plates with small $\frac{1}{4}$ in. diameter shot between them, caution being taken not to have the shot too large. With a light building the $\frac{1}{4}$ in. shot has been found to be very effective. The foundations in every case should be free and not in contact with the surrounding soil.

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